THE CONTRADICTIONS OF ECONOMIC GROWTH: ENVIRONMENTAL POLLUTION, ILL-HEALTH AND ECONOMIC DEVELOPMENT IN HOUSTON, TEXAS

by

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ABSTRACT

The core theme of this thesis is the potential contradiction between the objective of economic growth in terms of the sustenance of the natural environment and human health. The basic research theme is the identification of the underlying political and economic processes that relate to rising air pollution and corresponding ill-health in cities. It explores the relationship between air pollution and child ill-health in Houston, a highly developed US city. The analysis points out that since the early 1900s, there has been rampant unregulated economic growth in Houston and that weak environmental protection has contributed to both past and current concentrations of industrial pollution, the net result of which is that the environment is severely damaged and human health is deleteriously affected.

The thesis indicates theoretical and epistemological limitations in emerging interpretations and highlights that air pollution and ill-health are not simply physical or social problems but they reflect the integration of biological mechanisms and political and economic priorities. This thesis reconceptualizes the connection between the economy and the environment, integrates abstract and empirical investigation, defines the structural character of spatial relations, combines global economic processes with local patterns of environmental degradation, and links historical growth to ecological and health changes.

The field-work consisted of a large comparative household survey to examine local air pollution and child ill-health. It was informed by investigations of institutions and documents and complemented by semi-structured interviews. Clusters of child ill-health were found in low- and high-income households in areas near petrochemicals. While it is clear that the socio-economic circumstances of each household influenced the state of child health, this study demonstrates that spatial relations also played a significant role in the relationship. The procedures and analyses are conceptualized through a critical realist methodology, contextualized in a political-economy approach and framed within a theoretical perspective of historical social relations.

This thesis is dedicated to Yuti and Adil

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Finally, and deserving of special mention, my husband Yuti for his help and support. He accompanied me to many interviews in the most dangerous areas of Houston. Special thanks also to the LSE S504 postgraduate community for their academic support and their stimulating human input throughout the research.

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ABBREVIATIONS

APCHS	Air Pollution and Child Health Survey
AQCB	Air Quality Control Bureau, Houston
BACT	Best available control technology
CDC	Center for Disease Control, USA
CO	Carbon monoxide
HAS	Houston Area Survey
HHSD	City of Houston Health and Human Services Department
HRM	Houston Regional Monitoring
HSA	Health Service Area
HSA	Health Service Area
LRI	Lower respiratory tract
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NAMS	National Air Monitoring Station
NO_2	Nitrogen dioxide
NOTF	Nuisance Odours Task Force
O_3	Ozone
PM-10	Particulate Matter
PMSA	Primary Metropolitan Statistical Area
PPB	Part per billion
PPM	Part per million
PSI	Pollutant Standard Index
SO_2	Sulphur dioxide
TACB	Texas Air Control Board
TES	Texas Environmental Survey

TSP	Total suspended particles
URI	Upper respiratory tract
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

CHAPTER ONE

INTRODUCTION

The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. This pollution is for the most part irrecoverable; the chain of evil it initiates not only in the world that must support life but in living tissues is for the most part irreversible (Carson, 1962, p. 6).

There is widespread agreement that environmental degradation in the US and in Europe accelerated dramatically in a time of rapid urban growth, increasing industrial activity and the expansion of world markets after the Second World War. The deleterious human impact on the environment mounted rapidly, with increasing scientific evidence of an environmental crisis.

Since Carson's (1962) book, there has been a series of influential publications that have highlighted a tension between such growth and the environment (see e.g., Meadows *et al.*, 1972; Watts, 1983; Bartelmus, 1986; WCED, 1987; Pearce *et al.*, 1989; Pearce, 1991; Jacobs, 1994). One strand within this literature is resource depletion, (Hecht and Cockburn, 1989; Blaikie, 1985; Prestt, 1970). The other strand is pollution (Bertell, 1985; Ives, 1985; Blowers and Lowry, 1987; Blowers, 1989; Pollock, 1989; ENDS, 1994; World Resources Institute, 1994). Within the second strand, concern over the relationship between air pollution and ill-health, particularly in large cities, had already existed for some time (International Labour Office, 1927; Spence, 1954; Kapp, 1954; Radford, 1976; Agency for Toxic Substances and Disease Registry, 1988; Dockery, 1989, 1993; FoE, 1991; Médina and Quénel, 1994; Department of Health, 1995). However, concerns over health matters made their appearance in particular in the epidemiological and biological disciplines. In the political and economic environmental agenda, health issues have received a lower profile than other ecological problems. Politicians and social researchers have apparently underestimated the magnitude of the health damage caused by medium and low-level industrial and urban pollution and overlooked the environmental impact of economic growth. Natural scientists have generally reduced the problem to its biological dimensions.

The linkage between urban air pollution and ill-health was already recognized and studied in the nineteenth century. However, only since the 1970s have scientists systematically focused on the problems of escalating air pollution in cities and the subsequent disarrangement in ecological and human functions (e.g., Caprio *et al.*, 1975; Radford, 1976; Dockery *et al.*, 1989; Schwartz and Marcus, 1990; US EPA, 1990; Romieu *et al.*, 1990; Robertson *et al.*, 1991; Quénel and Médina, 1993; ENDS, 1994a). For example, a strong correlation between the number of deaths and presence of high levels of total suspended particulates (TSP) or sulphur dioxide (Schwartz and Marcus, 1990) was uncovered for the London winters of 1958-1972. Significantly, the strength of the correlation remains despite the fact that absolute levels of mortality and air pollution were lower than in earlier years' winters. It has been argued that in cities with high levels of air pollution mortality rates are higher than in less polluted cities (Lawrence, 1993; US EPA, 1990). In fact, in Athens, Barcelona, Caracas, Mexico City, Paris, and Tokyo, triggers such as sulphur dioxide, airborne allergens, ozone pollution, and heavy traffic have been correlated with mortality from respiratory problems, increase in emergency visits to hospitals, with asthma attacks, frequent cardiovascular disease, and with general respiratory symptoms (see, for e.g., Katsouyani *et al.*, 1993; Médina and Quénel, 1993; Quénel and Médina, 1993; Sunnucks and Osorio, 1992; Romieu *et al*, 1990).

In spite of the difficulty in collecting information on the relation between lower levels of air pollutants and the effects on health through conventional methods of assessment, the quality of epidemiological evidence has improved dramatically. It is striking that not only high levels of pollution but also those below the official safety standards seem to precipitate ill-health (see e.g., Romieu *et al.*, 1993; Read and Read, 1991; WHO, 1979). The immediate and acute effects of episodes of high concentrations of air pollution have been raised often by authorities and researchers, It is, however, the combination of moderate to high levels of urban air pollution and 'the long-term or chronic effects of air pollution with their insidious results which cause all the controversy' (Bach, 1972, p. 51).

Available research models have emphasized and reproduced a reductionist, separationist and ahistorical view of society reinforcing in this manner widely held beliefs about the causes of hazardous environments, the origins of ill-health, and the best political alternatives for dealing with them. The role of the sciences in explaining the linkages between economic growth and environmental degradation have come under increasing scrutinity due to their inadequacy for the task (see, for example, Benton, 1994; Oakley, 1992; Dickens, 1992; Yearley, 1991a, 1991b; Redclift, 1984; Caldwell, 1977). Principal difficulties are that the foundations of the separation between the social and the natural sciences, based as these are on dualistic modes of thought, go very deep. They are in a very important respect organizing categories, both shaping scientific thought and research, and structuring everyday non-scientific and common-sense contexts of thought. We have thus a dichotomous understanding, one based on social theory, the other on natural science.

Social theory and the natural sciences can certainly continue to make major contributions to the understanding of environmental problems, but the danger is that they will do so within their comparatively distinct disciplinary compartments. Yearley argues that although most environmental problems are those of the natural world, and accordingly demand expertise in the natural sciences, 'this demand is by no means exclusive' (1991a, p. 184). Similarly, Dickens suggests that sociology constructs itself 'as a watertight discipline largely by creating an impermeable division between itself and the natural sciences' (1992, p. 19). In fact, the social and the natural sciences have made great strides in their own specialities and each now has its own well-developed discourse. Nonetheless, the problem is that they are talking past each other even though the sharing of data has become common practice between the disciplines. The sciences have competed with each other to become the explanatory tool for environmentally related problems. The contribution of the social and natural sciences is essential but their present implicit discrete, and therefore limiting character, is highlighted. The question of how environmental and social reality is constructed in the sciences has been neglected in the environmental debate, a shortfall which has had particular implications for the understanding of the causative powers of economic growth as they relate to the natural environment and human health. To aid this process of re-vision, the thesis takes a critical stance and focus on the taken-for-granted which has been usually disregarded (Adam, 1994).

Certainly, social researchers have examined the links between the economy and the environment, and between human health and the economy. While their work has provided useful information, conceptualization of how pollution and ill-health are mediated by society has been largely skewed. Environmental events have been wrongly interpreted as either a reaction to the supposedly natural limits to economic growth or as the inevitable consequence of modernization and industrialization. The implications of the process of capital accumulation and the course of rising environmental degradation have often been improperly understood and perhaps even sidestepped. Neither have scientists sufficiently explored the inter-relationship between spatial manifestations of economic growth, air pollution and illness. In direct contrast to the works of mainstream scientists, here the nature of the interrelationship is seen neither as simple nor straightforward.

In view of persistent air contamination and severe health consequences, particularly for children, the thesis claims that air pollution and ill-health in cities are better understood not simply as a medical or ecological problem, but through three strategies. These attempt to transcend the empirical restrictions of the field work and the abstract notions of theory. First, it is necessary to recognize that underlying social processes and biological mechanisms interact to produce both environmental degradation and ill-health. Second, economic and political forces at work in society need to be examined. This requires a critical exploration of historical, political and economic priorities and environmental changes since the early twentieth century, i.e., industrial activity, rampant economic growth, increasing toxic emissions, prolonged environmental damage, and examination of institutions and structures that regulate the environment and health care. Third, it is essential to assess in practice both the degree of environmental degradation and the extent of child ill-health in temporally and spatially specific contexts to determine the complexity of the question and to uncover the links to economic and political structures.

1.1 Aims and Objectives of the Thesis

The aim of the thesis is to develop a political and economic explanation of the relationship between environment and society in terms of the contradictions of capitalist economic growth. The objective of the thesis is to focus on the current relationship between air pollution and ill-health in major cities. A study of this relationship allows an examination of economic growth trends which have disregarded the adverse environmental effects of uncontrolled and widespread industrial and urban development and exposes the discussion of economic prosperity as opposed to environmental degradation and human ill-health. This thesis argues that the relationship between air pollution and ill-health in major cities is better understood through a combination of analyses: a theoretical conceptualization of historical processes which currently shape social relations, empirical studies of the present events, the recognition of ecological and health mechanisms, an analysis of economic development and assessment of government regulations.

The venue of study is the city of Houston, and a sample of 300 households within the city is examined. The thesis is concerned not only with the more traditional areas of ill-health distribution, levels of air pollution, and the role of household conditions in triggering ill-health. It also examines the questions of why there is so much air pollution in the city; how children become ill; how economic, environmental and medical institutions affect both the state of the environment and health; which social processes and natural mechanisms are activated and why; and how spatial variation of effects indicates the interaction of political and physical processes.

The contribution of the thesis falls into three areas. First, it produces original systematic evidence on a subject on which there was little information available and analyzes the significance of its spatial patterns. Second, it elaborates a theoretical interpretation of geographical location that integrates national and international dimensions of the process of capital accumulation, the structural character of spatial relations, local air pollution and ill-health, reconceptualizing in this way the complex relationship between environment and society. Finally, it enhances the operationalization of critical realism, and develops an integrated approach of comparative study with quantitative, causal, and qualitative analyses. The thesis is designed to produce causal explanation and to improve substantive research methods for environmental issues. Its findings have the potential to contribute to the pragmatic area of pollution control and economic growth.

There exists a wide range of theoretical formulations and empirical analyses concerning environment, society and ill-health. Unfortunately, there is little common ground among these approaches, the intersections are few, and no single approach addresses the enquiry in its totality. Overall, existing approaches to environment and health have characteristically failed to understand elementary conceptual and methodological distinctions. Low priority has been given to the basic conceptualization of objects, the process of capital accumulation at local and international levels has been ignored, and the physical and social dimensions have been systematically separated. Initiating analysis with these theoretical formulations implies numerous difficulties.

The study of social and physical problems which comprise the bulk of the environmental and health research agenda, has presently become dominated by underlying spatial perspectives which are regionally constituted and perceived as an analysis of location-specific deployment patterns. These have usually been ascribed to the areas of epidemiology and medical geography. This research is characterized, on the one hand, by the use of spatial variation in individual circumstances as a means of discussing environmentally related problems. On the other hand, there is a reluctance to question the way in which these spatial environmental and ill-health patterns are produced by the combined actions of systemic forces in society, and how, in turn, ecological and spatial patterns that are related to political and economic structures affect local conditions. It is precisely this latter issue which I wish to address in the following chapters and to call for a new, critical approach to contemporary environmental problems and their spatial forms.

In my research, the key questions are related to how the precise combination of economic and political structure and practice can be established, what methods to apply to study the social and natural worlds, and what difference space makes in practice. These problems are approached in theoretical terms and the case study of the city of Houston and the household survey give these philosophical questions more empirical relevance. A review of the literature on environmental degradation and health shows that most research builds upon a dichotomous view of the world and has neither achieved the goal of causally linking social and natural events nor avoided the conceptual separation of the two. An objective of this thesis is to bring the social and the physical worlds closer in analytical and epistemological terms.

A review of the current state-of-the-art of theoretical modes of analysis of contemporary urban pollution and ill-health shows that, although important information has been revealed in the sciences, approaches have been narrowly constructed. It is the contention of the thesis that the origin of the theoretical limitation in research approaches lies in the philosophical views long adhered to in this type of research. The most popular methodology to address the relationship between air pollution and ill-health is positivism, or the scientificist method. Positivist research has been either biological reductionist or social reductionist. Reductionist research in the natural sciences has focused on the physical, descriptive and mechanical aspects of the relationship between air pollution and ill-health. The social reductionist position focuses almost exclusively on the effects of socio-economic and individual circumstances and the health outcome and avoids situating societies in a general political framework and even less, within the international division of labour.

The two branches derive from a sharp separation between nature and society. Commonly, the events are addressed as discrete rather than linked. The reductionist perspective overlooks the fact that physical and social realities are continually amenable to mutual influence. In the reductionist perspective, the role of space has usually been misunderstood and the influence of economic and political structures ignored. A second perspective overemphasizes economic structures that influence the relationship of air pollution and society. This approach has the consequence of excluding a number of dimensions of social analysis. It overlooks the natural mechanisms which give rise to environmental concern. It ignores the strong role of local structural variation and overlooks the role of space in any relationship. The two perspectives so far are based on misconceptions which reveal the inherent weakness of mainstream thought, because it is dependent upon an outmoded interpretive paradigm.

The epistemological perspective adopted in this thesis is that of critical realism. As opposed to positivism, in critical realism the study of social reality implies the examination of both observable and non-observable events, i.e., the underlying processes of causality. Critical realism recognizes the domains of mechanisms, processes, events and experiences (Sayer, 1992; Sarre, 1987; Bhaskar, 1975). Hence, the thesis operates on the principle that, to establish knowledge, we also need to recognize the power of things to cause events and ways of acting (Sayer, 1992). The study cuts across the natural and social sciences - environmental sciences, epidemiology, geography, green economics, sociology and politics - but it is well within the political and economic branches of the social sciences. The empirical method of research combines intensive and extensive investigations and comparative design is employed.

In the next chapters I will demonstrate, first, the need for new modes of explanation, conceived by critical realist methodology, to achieve an understanding of powerful political and economic forces and biological mechanisms that have altered the environment in general and air quality and child health in particular. Second, I will show the analytical validity of studying spatialized forms of social and biological empirical variations, and will highlight the historical and structural character of patterns of environmental degradation. The thesis is framed within the emerging debate which challenges traditional duality in scientific research and searches for a new type of science in which social and physical disciplines are brought within a single unified analytical framework.

1.2 The Structure of the Thesis

The thesis is divided into four main parts: conceptual framework, contextual background, the survey and findings, and conclusion. The first part describes the theory and methodology used and is made up of Chapters 2 and 3. Chapter 2 starts by contextualizing present air pollution in cities within the perspective of economic growth and goes on to introduce substantial epidemiological evidence of a link between child ill-health and increasing air pollution in cities. It gives the different conceptions of the production of both environmental degradation and ill-health and provides an overview of the environmental debate. The limitations in atomistic views of reality and ahistorical positions are outlined. It elaborates the theoretical approach of the thesis. Chapter 3 describes the methodology, defines the critical realist tools employed, and presents the sources of information used for the identification and analysis of child ill-health and levels of air pollution in Houston. The chapter addresses conceptual aspects of the method, of extensive and intensive research and of causality, as well as providing an explicit description of the research strategy, i.e., contextual research, survey and comparative analysis. A causal model which relates macro- and micro-structural levels and integrates the modifying role of geographical location is developed.

The second part of the thesis makes up the contextual framework of the study. Chapter 4 analyzes the parallel historical processes of population growth, economic development, and environmental degradation in the Houston region. It discusses interpretations of economic growth, assesses present and past levels of air pollution in the city and characterizes Houston as a place of contrasts where wealth and misery stand side by side. It highlights patterns of spatialized risk, points out too the coincidence of effects in highly industrialized areas, and addresses the findings of two regional environmental surveys. The objective of Chapter 5 is three fold. It starts by examining the institutional dimension of environmental regulation. Thereafter it assesses the system of health care provision and then analyzes the remarkable extent of public ill-health and of mortality from respiratory cancer in Houston in relation to the rest of the USA.

The third part of the thesis discusses original information on the reported state of child health, household socio-economic circumstances, and reported local air pollution gathered in the survey and the comparative study. Chapter 6 describes and analyzes the role of household micro-structural factors on the health of children. The extent and type of child illness is analyzed in relation to a range of issues which have been identified in the literature. The modifying role of spatial location of the household in relation to sources of industrial air pollution is assessed throughout the chapter. Although it emerged that how people live is crucial for their health, where they live significantly affects the incidence of child ill-health. Chapter 7 looks specifically into air pollution as the main characteristic that differentiates the location of the sample households, and thoroughly examines the effects of exposure to local air pollution. The structural character of the spatial relationship is highlighted. Additional exposure is also addressed.

In the last part, Chapter 8 brings together the themes and issues developed in the thesis. Chapter 8 interprets the findings of the thesis in the light of contextual research and the critical realist framework and produces a thorough explanation of the problem of air pollution, economic growth and child ill-health in Houston. It formulates the conclusions of the thesis by developing substantive contributions to research and to the wider debate. The boundaries of the research are explained, and a number of potential areas for further research are suggested.

CHAPTER TWO

ACCOUNTING FOR THE RELATIONSHIP BETWEEN AIR POLLUTION AND ILL-HEALTH

2.1 Introduction

The social and natural sciences have produced a range of theories which are relevant to environmental and health questions in industrialized societies. Biomedicine, ecology, geography, economy and sociology have each contributed significantly to our understanding of environmental degradation, its effects on human health, and the nature of both the environment and society. Such disciplines, however, have characteristically conceptualized the natural environment, human health and social questions as discrete entities. Consequently, the interrelationships of society, environment and health have often been neglected, as well as their historical context. In the main there has been an unfortunate fragmentation of knowledge in these fields, preventing a crucial synthesis. It is the claim of the current research that this is due mainly to restrictive philosophical stances.

This chapter has three objectives. First, it outlines the changing character of air pollution in cities since the late 19th century, contextualizes air pollution within general economic growth trends, and points out the health implications of considerable levels of urban air pollution. Second, it examines the alternative explanations for these issues in the literature and highlights those elements which are useful. The dominant theoretical assumptions and methodological strands in these explanations are discussed. Finally, it defines the nature of the relationship between air pollution and ill-health and establishes the theoretical framework of the thesis.

2.2 A Critical View of Rising Air Pollution and Growing Economy

What has given the environmental debate an added urgency is the pace at which natural resources are being depleted and the environment polluted (Redclift, 1984, p. 40).

The aim of this section is to describe the environmental changes that have taken place since the late nineteenth century and to suggest general historical economic trends that relate to pervasive contamination of the air in large cities. Clearly, the relationship between ill-health, environmental degradation and economic growth is more difficult to define than, say, the relationship of food scarcity, land erosion and agri-business in countries of the Third World. The fact that there are so many interacting pollutants and that the level of concentration of air contaminants is highly affected by climatic and topographic variables makes the isolation of environmental factors the most difficult to measure and reproduce. Equally, humans are usually exposed to a number of ill-health triggers: poverty, deficient health care provision, individual behaviour, biological factors and hazardous exposure. To establish the economic and political origin of air pollution and ill-health in cities is problematic though necessary.

2.2.1 *The Historical Evidence for Air Pollution in Cities, 1870-1980*

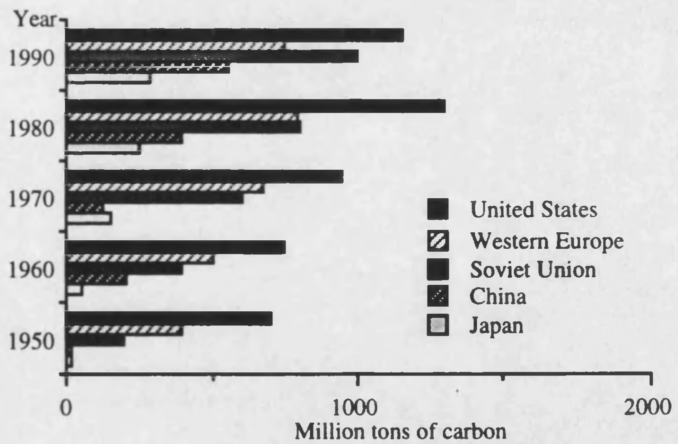
Modern urban air pollution dates at least from the eighteenth century. From this period, fossil fuel usage increased exponentially due to the burning of coal as an energy source in nearly all industrial processes and as the dominant domestic fuel. Although these developments were thought to reflect growing wealth and the introduction of new technology, they brought an increase in air pollution which began to affect the lives of cities' inhabitants.[1] Levels of atmospheric pollution have escalated considerably world-wide after the industrialization of society in the

[1] According to Brimblecombe (1988), walking the streets of London in the early eighteenth century was not a pleasurable experience. One stood a good chance of being doused in a soot-laden shower of rain or engulfed by an obnoxious mist.

eighteenth century, and particularly since the 1950s, regularly exceeding international health guide-lines (Médina and Quénel, 1993). It is suggested here that sustained capital accumulation and growth, particularly after the Second World War, have been the main underlying historical process and economic structure of environmental changes.

Carbon dioxide concentrations in the atmosphere are now 27% higher than their estimated pre-industrial levels. These are clearly paralleled by increases in global carbon dioxide emissions, which, since 1950, have risen 278% (World Resources Institute, 1994; Brown, *et al.*, 1989; see Figure 2.1). Although sulphur emissions have declined over recent years in industrialized cities, evidence for a decline in nitrogen emissions is less clear. In London photochemical precursors, i.e., nitrogen oxides and VOCs, and localized high concentrations of carbon monoxide are a major concern. Low-level ozone concentrations in the UK are rising by 1-2 % per year and background concentration is now in the range 10-20 ppb, twice the level of a century ago (ENDS, 1994b).[2]

Figure 2.1 Carbon emissions from fossil fuels, 1950-1987



Source: Data from Brown et al. (1989, p. 9).

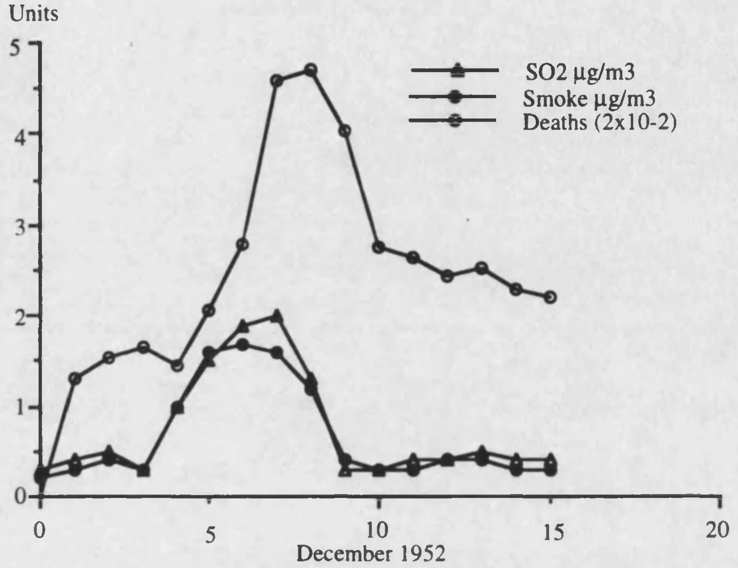
[2]In Britain, some two decades after the Second World War, a period of sustained growth saw corresponding levels of dereliction and pollution. In Bedfordshire, brick-making flourished, but its noxious by-products went uncontrolled (Blowers, 1984). Marston Vale in Bedfordshire was the heart of London Brick country where some of the largest brickworks in the world were located (Blowers, 1984). In its hey-day, chimneys dotted over the area would have belched contaminants into the surrounding countryside. Brick production brought with it a sulphurous stench and smoke, and also toxic fluoride, known to be detrimental to health.

High concentration of particulate matter in the air had long been a recognized health danger (Schwartz and Marcus, 1990). The historical evidence shows that very high levels of air pollution have corresponded with excess mortality. In the week of fog in December 1873, for example, it was estimated that there were 700 more deaths than normally expected in London at that time of year; in 1892, the number of deaths as a result of high concentration of sulphur dioxide was estimated to be 1000 (see Table 2.1) (Brimblecombe, 1988).

Many of the adverse effects of high and moderate levels of air pollution - as opposed to extreme levels - on human health had been described with remarkable accuracy early in the twentieth century. In 1913, smoke particles were referred to 'as carriers of the obnoxious products of human fatigue which irritate ... eyes, nose, throat, lungs, and gastro-intestinal tract, increase the susceptibility of gastro-intestinal, pulmonary and nasopharyngeal disorders ..., and may tend to hasten premature decay' (in Kapp, 1954, p. 70). In the 1950s, smoke was identified as the cause of the loss of daylight and ultraviolet light in cities. This loss, it was claimed, might have had the most injurious long-time effects on human health by inhalation of smoke-polluted air, compared to the immediate and evident losses resulting from the more rapid deterioration of building materials, metals and paint coatings.

Health risks were such that during the 1952 London Fog, the so called pea-souper fog, which was the result of severe concentration of industrial and domestic emissions combined with atmospheric inversion, the authorities placed ammonia bottles with wicks in hospital wards to neutralize high health toxicity of acid aerosols (Read and Read, 1991). During this episode, people died at a higher rate than in the cholera epidemic a century earlier (Pearce, F., 1992; see Figure 2.2). In one week alone, the death rate among children doubled. The acidity of the air, which contained soot and sulphur dioxide from domestic and industrial coal emissions was the cause. Simple clinical observation during episodes of high particulate air pollution in Donora, USA, and in London later on[3] suggested that particles were a cause of premature mortality (US EPA, 1982).

Figure 2.2 Number of deaths and pollutant concentrations in the London smog of 1952



Source: Adapted from Brimblecombe, 1988, p. 168.

~~Once~~ since Mexico, where records of severe atmospheric contamination in Mexico City have been kept since the early 1920s, became an active producer of oil in the 1950s unprecedentedly high concentrations of suspended particulates, lead, benzene and sulphur dioxide ~~have~~ were been registered (Schteingart, 1989; Bravo Alvarez, 1987). In the 1990s, about 30,000 industrial plants, 3 million vehicles and thousands of smaller industrial sites contribute to air contamination in Mexico City (Comisión Metropolitana, 1992; Sunnucks and Osorio, 1992). The percentage of journeys undertaken by private cars almost trebled between 1966 and 1985 while journeys in high-capacity transport decreased by about 60 % during the same period (Ward, 1990).[4]

[3]In the earlier part of the twentieth century, episodes of acute severe particulate air pollution occurred in many European and American cities - in the Meuse Valley, Belgium, 1930; in Donora, Pennsylvania, USA, 1948; in New York, USA, 1953; and in London, UK, in 1952, 1956, 1957 and 1962 (FoE, 1991; Bach, 1972). These episodes led to rises in mortality chiefly because of increased deaths from pneumonia and cardiovascular disease.

[4]In Mexico City, remarkable growth of economic activity, particularly manufacturing between 1930 and 1980, has been linked to high levels of air pollution. For example, the percentage increase in

Although scientific knowledge in the 1950s of how and why air pollution affected health was limited, substantial biomedical and epidemiological investigations since the 1970s have attested to the extensive damage that air pollution may cause to humans (and to animal and plants), strongly confirming the earlier insights (Cherni, 1992). These are still relevant, perhaps, more so now than ever before as later investigations show, including the evidence presented in this thesis.

While not denying the contribution of a variety of individual and biological factors to worsen the health of the population, analyses of excess ill-health in polluted cities have been conducted in such a fashion as to obscure the political and economic origin of environmental pollution and ill-health. In fact, it was not until extreme air pollution episodes struck large cities in the 1950s, that the UK and US governments considered the evidence of devastating health effects of air pollution for the purpose of regulating emissions (see section 5.2.1). Changes in air pollution legislation since the late 1950s have undeniably reduced particulates and sulphur dioxide levels in cities such as London, Los Angeles, New York, Beijing, Delhi and Seoul (UNEP and WHO, 1992).

European and UK legislators have considerably tightened controls on air pollution from the so-called 'stationary' sources of homes, commerce and industry. While not denying that this has led to improvements in many aspects of urban air quality, the improvement in air quality arising from the overall decline in domestic and industrial emissions has been offset to a large extent by remarkable industrial growth, emissions from widespread usage of mobile sources, and expansion of cities (Parliamentary Office of Science and Technology, 1994; UNEP and WHO, 1992). Notwithstanding that episodes of extremely hazardous air pollution have decreased considerably in American and European cities over the last 30 years, sources of toxic emission have multiplied many times, and in numerous cities the levels of

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number of industrial establishments grew from 6.8 in 1930, to 20.0 in 1950, 27.9 in 1970 and 29.5 in 1980 (Ward, 1990) contamination have risen dramatically in the last 20 years (see Figure 2.1). Air pollution continued to grow and have an adverse effect on the health of the population. The extent of excess deaths which occurred in subsequent episodes (see Table 2.1) and the large incidence of respiratory and other diseases plainly reflect these trends.

Table 2.1 Major London smogs and excess deaths, 1873-1991*

Year	*Month*	*Duration* (Days)	*Excess deaths*	*Maximum daily SO2 mg/m3*	*concentration Smoke mg/m3*
1873	Dec.	3	270-700	N/A	(a)
1880	Jan.	4	700-1100	N/A	
1882	Feb.	N/A	N/A	N/A	
1891	Dec.	N/A	N/A	N/A	
1892	Dec.	3	~1000	N/A	
1948	Nov.	6	~ 300	N/A	
1952	Dec.	5	4000	3700	4460
1956	Jan.	N/A	480	2800	1700
1957	Dec.	N/A	300-800	2800	3000
1962	Dec.	4	340-700	4100	1900
1975	Dec.	3	(b)	N/A	500-600
1982	Nov.	N/A	N/A	560	N/A
1991**	Dec.		160		

Source: Brimblecombe, 1988, p.124; adapted from Quénel and Médina, 1993
* The present World Health Organisation sulphur dioxide Air Quality Guide-line 24 hours is 100-150 ug/m3.
** The 1991 episode was caused by nitrogen dioxide.
(a) Smoke in the early fogs were 800 ug/m3 or greater.
(b) Not statistically significant.

2.2.2 *Urban Pollution and Ill-Health in the 1990s*

Today, the unhealthy environment of many large cities reminds us of tragic episodes of air pollution in the 1950s and related mortality in the past. Undoubtedly, the absolute concentration of industrial urban pollution has decreased noticeably since then, and its characteristics have certainly changed in relation to the type of air contamination registered in the past. Yet, in the last fifteen years, the similarly insidious impact of lower levels of air pollution on health, and the damage that new pollutants cause, have been increasingly recognized.

In the 1990s, there is substantial epidemiological evidence to show that increased risk of an asthmatic attack is associated with exposure to ozone concentrations (e.g., Hall, 1994; Lean,1994b; Lean, 1993b, 1993c, and 1993d;

Pönkä, 1991; Dockery *et al.*, 1989, Stock *et al.*, 1988; Holguin *et al.*, 1984). The number of young children with asthma admitted to hospital in Britain has increased 13 fold since 1960 (Lean, 1993a). The asthma epidemic is remarkable also in other countries. In Finland, military records show that between 1961 and 1989 the proportion of new recruits with asthma suddenly and dramatically increased 20 fold (Taylor, 1995). In 1994, one in seven children in Britain had asthma.[5] In the UK, it is now the greatest single cause of hospital admissions after heart disease and stroke, and kills more than 2,000 people a year (National Asthma Campaign, 1994) (see Appendix D for the health effect of separate pollutants).

In large cities of the Third World, in South America in particular, industrialization and consequent air pollution have produced similar outcomes. Not surprisingly, Mexico City has frequently been identified as one of the most polluted areas in the world (Elsom, 1996; Schteingart, 1989)[6] with almost half of all babies having dangerous levels of lead in the blood (Sunnucks and Osorio, 1992).[7] There is evidence to suggest that one out of three children living in the Chilean capital, Santiago, suffers from bronchitis, and visits to doctors for the treatment of respiratory problems are higher than the annual average world-wide. In the Brazilian city of São Paulo, which, unlike the rest of the country, is highly industrialised, respiratory disease is prevalent and is the most common cause of death for children under the age of four. Among people aged 60 and over in São Paulo, around 14% of deaths are caused by respiratory problems, compared with the average 8.6% for the rest of Brazil (Sunnucks and Osorio, 1992).

The recurrence in the 1990s of remarkably high levels of air pollution together with severe health consequences suggests that urban air pollution in cities nowadays

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[5]According to the National Asthma Campaign (1994), estimates of current prevalence vary, but between 12% and 15% of children have episodes of wheezing characteristic of asthma. A UK nationwide study by Stracham *et al.* (1994) of a group of children aged 6-17 found that 13% of the sample had diagnosed asthma.

[6]In addition to remarkable industrialization, between 1950 and 1992, the global vehicle fleet has grown tenfold and was expected to double from 1992 within the next 20-30 years (UNEP & WHO, 1992).

[7]Mexico city is encircled by mountains and subjected to prolonged periods of light winds and strong temperature inversions which trap the pollutants over the city (Elsom, 1996).

remains as much of a problem as it was in 1952 (see section 2.2.1). Subsequent air pollution episodes in London (see, e.g., Lean, 1995; Schoon, 1994a, 1994b; Lean, 1994a; Ghazi, 1992), potently indicate that other political, economic, or medical priorities have conspicuously diminished the importance of environmental protection. On the 39th anniversary of the Great London Fog, in December 1991, atmospheric conditions in the city closely resembled those of the days of the pea-souper.[8] Pollution from car exhausts combined with freezing temperatures to produce smog that exceeded levels in many of the world's dirtiest cities (Palmer and Ballantyne, 1991). 'The day Britain choked' caused an estimated 160 excess deaths while hundreds more experienced breathing difficulties (Lean, 1994b; Connor, 1994). Motorists in London were urged by the government to stop driving as winter air pollution reached the highest levels since records began in 1976 (Brown, 1991). The Department of the Environment clearly announced the health risks from high levels of air pollution, 'the high levels of nitrogen and sulphur dioxide will continue making it dangerous for asthmatics, bronchitics, elderly people and babies to go outdoors until tomorrow' (Lonsdale and Lockhart, 1991).

Following another pollution episode in July 1994, the biggest asthma outbreak ever registered anywhere in the world occurred over much of England (Lean, 1994c); '... the scale of the outbreak almost certainly meant pollution was a factor' (Hall, 1994). This happened as Britain was enduring the 'dirtiest' air summer recorded in this decade (Lean, 1994a). The chairman of the British Lung Foundation, Dr Malcom Green, announced:

> *An astonishing outbreak like this means something serious is going on. A likely scenario is that high pollution levels in the preceding weeks sensitized people's lungs. We have had plenty of thunderstorms in the past which have not led to such episodes. Air pollution has been increasing, and this is a warning that we must do something about it (Lean, 1994b, p. 1).*

[8]There have been further episodes of air pollution in the UK, in 1992 and 1995 but the 1991 episode has been the worst so far (Lean, 1995; Ghazi, 1992; Schoon, 1994 a; Schoon, 1994 b; Lean, 1994a). Inversion climatic conditions prevailed during the 1991 episode. Cold weather at ground levels could not be released due to warmer atmospheric pressure; this did not let fumes to disipate (Lean, 1995; Connor, 1994; Palmer and Ballantyne, 1991; Brown, 1991).

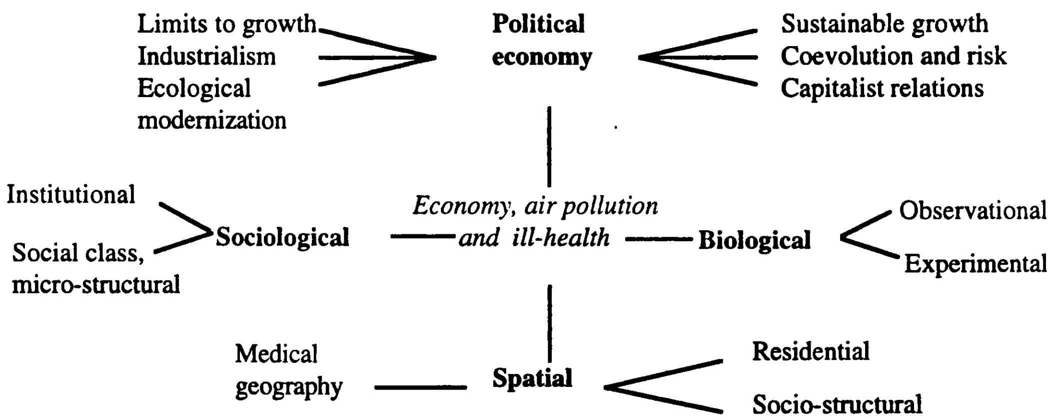
Considering the current poor state of the urban environment in many large metropolises (e.g., Mexico City, Athens, Los Angeles, Houston, London), and the rising evidence of a relationship between air pollution and ill-health, particularly in children, a number of issues need to be confronted. For example, why has the environmental balance in cities so frequently been disrupted? Why have environmental protection laws been so slow to incorporate adequate measures against obvious air contamination? How does economic activity relate to this problem? How do we explain that despite the fact that increasing urban air pollution is directly attributable to industrial, transport and urban expansion, economic growth has not been curbed in order to protect the environment or health? Why have human health and the environment remained so weakly protected? In summary, the relationship between air pollution and ill-health is complex and requires an adequate approach to understand it. Conventional research and political institutions have a 'disintegrated' view of the problem, and in this way, the structural processes that bring about air pollution and ill-health in cities have been hidden. The review in this section has established a historical causal connection between evidence of rising air pollution in cities, industrial and urban growth, and the incidence of mortality and ill-health. We move on now to assess the different approaches and interpretations that appear in the literature.

2.3 Alternative Approaches

The study of polluted urban environments and ill-health has been profoundly influenced by the infamous episodes of severe urban air pollution and death in the 1950s. Notwithstanding the strong social origin of these ecological changes, explanations of the phenomenon of rising pollution and disease nonetheless have typically relied on the natural sciences. Epidemiology, medicine and ecology, i.e., the biological sciences, have been adopted as the most useful disciplines to explain the problem. However, these are not sufficient. The trends of economic growth have been implicated in the rise of contamination in cities, and environmental regulations have mostly failed to maintain harmless levels of air pollution in cities. While modern industrialization has been identified as the cause of the destruction of the environment, the social process of capital accumulation and the power of multinationals, however, have usually been overlooked as the generating forces that have promoted industrial growth.

Three consistent elements in the interpretations of the relationship between air pollution and ill-health since the 1970s are shown to be endemic in environmental and social approaches: first, an artificial separation of the physical and social issues that link environment and society; second, a systematic ignorance of the influence of political and economic historical processes; and third, lack of concern for the causal role of structural spatial relations.

Figure 2.3 Fragmentation in the literature



The approaches can be classified in four major groups. The first group is concerned with developing a biological explanation of disease (see, for example, Dockery *et al.*, 1993, 1989, 1977; Goren *et al.*, 1990; Romieu *et al.*, 1993; Schwartz *et al.*, 1991; Agency for Toxic Substances and Disease Registry, 1988; Center for Disease Control, 1988; US EPA, 1986; WHO, 1979; Needleman *et al.*, 1979; Collins *et al.*, 1971).[9] Information is collected on individuals and on external environmental conditions which is then aggregated to allow statistical analysis to reveal regular associations between certain risk factors and disease. In this group of themes, disease is argued to be due to biological abnormality, but including external influences. Leading theoretical schools are observational epidemiology and experimental biology.

The second group of approaches, namely, those comprising the sociological perspective, considers the role of the micro-economy and of structural and institutional factors on health status. Three main issues are addressed in these discussions. A most influential debate has been over the relative effect of social class as defined by occupational status (Blaxter, 1990, 1981, 1983; Hicks *et. al.*, 1989; Hart, 1986; Black *et al.*, 1982; Hart, 1975; Colley and Reid, 1970; Dawson *et. al.*, 1969; Spence *et al.*, 1954) and on the role of income (Jolly, 1990; Dougherty, 1988; Golding, 1986; Townsend *et al.*, 1988). While income is a most important causal variable, this thesis shows that its effect is not independent of spatial factors. A further debate developed around the role of socio-economic conditions, such as housing and family structure (Blackman *et al.*, 1989; Golding, 1986; Hart, *et al.*, 1986; Spivey *et al.*, 1979; Yarnell and Leges 1977). A third theme focuses on the role of institutional health care and delivery of health services (e.g., Blaxter, 1990; Dougherty, 1988; Black *et al.*, 1982).

The third type of analysis is based on the spatial aspect of the enquiry and addresses the geographical distribution of health problems and environmental associations. Three mainstream debates that aim to provide clues to spatial variation and the aetiology of disease are relevant here: (i) medical geography; (ii) residential location; and (iii) 'space matters'. The first group explains disease distribution and focuses on specific properties of the physical environment and usually uses socio-

[9]For more detail on the health effect of sulphur dioxide, ozone, particulate matter, and lead see Forastieri *et al.*, 1992; Baghurst *et al.*, 1992; Bobak and Leon, 1992; Ransom and Pope III, 1992; Pönkä, 1991; Read and Read, 1991; Mallol and Nogues, 1991; Pope, 1991, 1989; Zwick *et al.*, 1991; Jaakkola *et al.*, 1990; Rutishauser *et al.*, 1990; Boussin *et al.*, 1990; Villalbí *et al.*, 1984; Wilson, 1983; Mahaffey *et al.*, 1982; Caprio *et al.*, 1975) (see Appendix D).

economic variables as controls (e.g., Cuzick and Elliot, 1992; Hatch, 1992; Gardner, 1991; Britton *et al.,* 1990; Sobral, 1989; World Resources, 1988; World Health Organization, 1979; Pyle, 1976; Morris, 1975; Howe, 1975; Gardner, 1973; McGlashan, 1972; Girt, 1972; Howe, 1972). The second group uses area level analysis and studies the relationship between deprivation and either mortality or morbidity (Macintyre, 1993; Phillimore, 1991; Blaxter, 1990, 1983; Blackman *et al.*, 1989; Townsend et *al.*, 1988; Caprio, 1975; Girt, 1972; Lunn *et al.,* 1970). The final group enquires into the importance of the spatial form for social analysis (Sayer, 1992, 1985; Duncan, 1989; Dickens *et al.,* 1985; Massey, 1987).

The fourth set of formulations focuses on the relationships between the economy and the environment (see for e.g., Benton, 1994; Hecht and Cockburn, 1989; Redclift, 1987, 1984; Hardin, 1977; Ehrlich and Ehrlich, 1970).[10] These studies shed light on issues related to the links between economic growth, industrialization and the environmental crisis. Severity of environmental degradation has shifted the discussion from the continuing viability of the growth model - a consensus which, since the industrial revolution, has held that expanding production is a good thing. It has moved (i) to neo-Malthusian 'limits to growth' concepts and the scarcity thesis of the early 1970s; (ii) to a critique of industrialization and modernization; (iii) to a search for means to grow economically but within ecological limits and to practise sustainable development and ecological modernization from the mid-1970s onwards; and (iv) to establish the interconnections between environmental degradation and capitalism as the central cause of environmental crisis and ill-health.

In the next sections, the debate over the causes of and appropriate explanations for the air pollution crisis in highly developed cities and its effects on human health will be considered as the background to the thesis' analytical model which will be developed in Chapter 3.

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[10]For a more extended literature see, for example, Blowers, 1993; Norgaard, 1994, 1985; Beck, 1992; Dickens, 1992; Blaikie, 1985; Porrit, 1984; Singh, 1976; Meadows *et al.*, 1972; Commoner, 1972; Forrester, 1970.

2.4 Biomedical Explanation of Illness and Environmental Contamination

A key approach for understanding the relationship between environmental degradation and health focuses on the ecological and medical mechanisms involved. The biomedical approach is centred around the natural sciences. It emphasizes biological processes, description of the events, statistical representation of the phenomena, comparative testing, and recognition of the independent nature of physical events. Unlike the other approaches, it stresses individual responsibility for ill-health and builds upon physical rather than social determinism as a causation of ill-health. It is possible to distinguish between two different biomedical models. The first is the epidemiological or the observational. Epidemiological designs are frequently complemented by demographic, social and environmental information in some form of causal correlation (Pyle, 1979; McGlashan, 1977).[11] Population data on public health are collected from archives and observations carried out by researchers.[12] Examination of air pollution levels originates in three main sources: pollution reports from officially located monitoring stations; research-purpose established monitoring stations; and atmospheric measurements such as wind, humidity and temperature. The second biomedical model is the biological or experimental. Experimental research collects biological markers and entails intervention by the researcher.[13] The focus of the analysis is now on the epidemiological literature because of its usefulness for the

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[11]The most common data included are age, sex, weight, height, educational level, smoking history, occupational exposure and medical history, some of which are part of standard questionnaires. Other variables often considered are type of cooking stove, child respiratory illness history, number of persons per room, years of schooling of the parents, day of the week and month preceding symptoms, the father's country of origin, parents' respiratory problems and level of alcohol consumption.

[12]These are mortality and morbidity registries; surveys, usually employing epidemiologically standardized questionnaires on respiratory symptoms which follow one of the three basic types of observational design: cross-sectional, case-comparison and cohort observational; medical examination, most often, spirometric tests of pulmonary function; routine and emergency admission to hospital for respiratory failure; and school absenteeism and school attendance rates.

[13]Examples are blood molecular and genetic testing; urine tests for toxic components; and examination for lung tissue damage.

theme of study. The section reviews the epidemiological literature and critically examines the methods of research.

2.4.1 *Epidemiology of Child Ill-Health and Air Pollution*

Epidemiological studies of the health impact of air pollutants strongly indicate (a) that air pollution can be very harmful to human health; (b) that children and infants are particularly vulnerable; and (c) that levels of air pollution do not need to reach extreme levels in order to be harmful. dose-response

Morbidity, rather than mortality, seems likely to be a more sensitive measure in studies of relatively long-term and high, but not extreme, levels of air pollution (Davies, 1994). In cities with high particulate pollution, rates of respiratory symptoms are especially high among children (Dockery *et al.*, 1989). Schwartz *et al.* (1991) found that chronic cough, bronchitis and chest illness in both children and adults, controlling for household variables such as parental smoking, type of cooking stove, and history of respiratory illness, were positively associated with all measures of particulate pollution.[14] A study in Israel similarly showed how greater prevalence of most respiratory symptoms was found among children who lived in a more polluted than in a less polluted area, having controlled for household condition (although these were also important) (Goren *et al.*, 1990). Infants are specially vulnerable to air pollution (Collins *et al.*, 1971). A particularly useful study of air pollution and infant mortality carried out in the Czech Republic between 1986 and 1988, observed substantial correlation between post neonatal respiratory mortality and total suspended particle and sulphur dioxide levels (Bobak and Leon, 1992). Significantly, the Czech Republic has some of the highest levels of air pollution in Europe with the second highest annual emission of sulphur dioxide in Europe in 1987.

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[14]Children with reported persistent wheeze or asthma were found to have substantially higher reporting rates of respiratory illness as well as lower pulmonary functions. The authors suggested that children with hyperreactive airways may be particularly susceptible to other respiratory symptoms when exposed to TSP, sulphur dioxide and nitrogen dioxide (Schwartz *et al.*, 1991).

A number of studies had observed that the effects of acute exposure to PM-10 cause a decline in lung function - often accompanied by symptoms such as chest pain, coughing, nausea and pulmonary congestion, a decline which can persist even weeks after a single pollution episode (Schwartz *et al.,* 1993; Ransom and Pope, 1992; Dockery *et al.*, 1989). High levels of school absenteeism in Utah Valley, USA were associated with exposure to high concentrations of PM-10 emitted by an integrated steel mill (Ransom and Pope III, 1992; see also Pope III *et al.*, 1991). Hospital admissions in Barcelona, Spain, increased when air pollution was very high, and 48% out of all patients admitted were suffering from asthma or bronchospasm emergencies (Villalbí *et al.*, 1984). A 20% higher risk of children developing respiratory problems in Mexico City was found when they were exposed to ozone pollution peak, > 0.13 ppm, for two consecutive days in 1988 (Romieu *et al.*, 1993).

Substantial numbers of studies suggest that even concentrations of pollutants lower than those given as guide-lines in many countries may increase the incidence of respiratory illness. An early large-scale study carried out by the World Health Organization significantly revealed close correlation between low levels of air pollution and various respiratory indices in children from eight different European countries: Czechoslovakia, Denmark, Greece, the Netherlands, Poland, Romania, Spain and Yugoslavia (WHO, 1979). A particularly useful three-year study of asthma and low-level pollution in Helsinki has shown that, among children, exposure to atmospheric ozone and nitric acid was significantly correlated with admissions to hospital even though the levels of these pollutants were fairly low (Pönkä, 1991). Also, changes in the biochemistry of the lungs have been documented at ozone levels well below international safety limits. Read and Read (1991) point out that long-term exposure to ozone for 6-7 hours at relatively low concentrations, that is 0.08 ppm, has been found significantly to reduce lung function in normal, healthy people during periods of moderate exercise. Further, similar investigations carried out in Italy (Forastieri *et al.*, 1992), Spain (Mallol and Nogues, 1991), Switzerland (Rutishauser *et al.*, 1990), Mexico (Romieu *et al.*, 1993), France (Quénel and Médina, 1993; Boussin *et al.*, 1990), and Finland (Jaakkola *et al.*, 1990) show that the frequency of respiratory symptoms in children is correlated to levels of contamination which usually do not exceed established 'safety limits'. The evidence in these studies potently support the arguments that moderate to high levels of air pollution in cities are also highly deleterious for human health (see Appendix D for the health effects of each separated pollutant).

2.4.2 *Benefits and Limitations in the Biomedical Approach*

The biomedical literature furnishes the present research with essential epidemiological and medical information about the relationship between air pollution and ill-health. This is necessary because the physical world has independent characteristics which need to be considered. Nonetheless, the biomedical approach to an understanding of the relationship between environmental pollution and ill-health cannot be adopted on its own because such a perspective entails four types of limitation.

First, the explanations for the correlation between air pollution and ill-health spring from positivist epistemology which accounts for observed phenomena by the development of laws based on empirical regularities, 'it is implicitly or explicitly assumed that theory and analysis are supposed to seek out generalizations of relations among empirical objects and events themselves and not abstractions of what produce them' (Sayer 1982, p. 72). This type of scientific knowledge can only be gained by the judicious use of the senses to observe and measure 'facts' that are used to refute and test hypotheses and theories. The analysis presupposes that all relations are external, quantitative and in most cases do not permit identification of internal, qualitative mechanisms of causation. A fundamental requirement of biomedical studies is that observations are supposed to be independent of one another, as if they existed, in reality, in isolation. It is presumed in positivist science that by understanding individual behaviour it becomes possible to understand society. This position ignores the fact that society is an open system with structures and emergent powers with important and influential spatial and social features. Therefore, air pollution and ill-health can only be partly understood by disaggregating the relationship into its biological components and associating them statistically.

Second, the weakness of inferring explanations from correlations is illustrated in the story of the drunk who tried to discover the causes of his drunkenness by using such methods. On Monday he had whiskey and soda, on Tuesday gin and soda, on Wednesday vodka and soda and on other nights when he stayed sober, he drank nothing; by looking for the common factor in the drinking pattern for the nights when he got drunk, he decided the soda water was responsible. Now, the drunk might possibly have chosen alcohol as the common factor and hence as the cause. However, what gives such an inference credibility is not merely that alcohol was a common factor but the pre-existing knowledge that it has a mechanism capable of inducing drunkenness. The implications for right deductions provided by this seemingly trivial example are certainly far-fetched even though for many applications in social science the explanatory situation is more complex. There is not one but several equivalents of the soda water and it is much more difficult to separate soda water and alcohol (Sayer, 1992). Nonetheless, this example illustrates my point. While looking for differences between situations seems sensible, such an approach is inconclusive in causal terms because there can be regularity without causality (Jones and Moon, 1987). Crucially, such notions make no reference whatsoever to causal mechanisms. In summary, neither common nor distinguishing properties need be causally relevant.

This takes us to the third type of limitation. Even when the physical mechanisms of causation have been analyzed, these explanations tend to be blind to variety of contingent conditions which may affect the final outcome. For example, children in deprived social conditions are vulnerable to the effects of environmental lead on two counts: first, they are exposed, as anybody else, to the properties of atmospheric lead which causes neurological and behavioural damage (see for e.g., Baghurst *et al.,* 1992; Agency for Toxic Substances and Disease Registry, 1988; Centers for Disease Control, 1988; US EPA, 1986);[15] second, their poverty - hence precarious health care, housing near industrial areas and roads, and deficient diet - makes them more vulnerable to these effects (Mahaffey *et al.,* 1982). Extending the linear model of correlation and searching for associations of similarity and including the social, e.g., social class, smoking habits, or geographical differences, as many epidemiological studies have done, does not constitute a sufficient break with basic deficiencies of traditional scientific methods, for 'while the biomedical model has been extended backwards, it has not been extended far enough to include societal, structural variables' (Jones and Moon, 1987, p. 316).

Fourth, following from the third limitation, positivist explanations are founded on an ahistorical and atomistic perception of reality. Positivist, as opposed to realist, analysis usually ignores qualitative features of key objects and abstracts from variation in their contexts; however, these are often linked and internally related. Indeed, it is precisely a qualitative discrimination between different types of relations and an identification of the connections between specific mechanisms of air pollution and health and their particular conditions that need to be explained. Child exposure to environmental lead depends on both, independent and conditional circumstances, as the above example shows. Lead has harmful properties but these need to be activated if it is to cause child health problems. Hazardous concentrations of lead are found in the environment primarily because it is used ubiquitously, e.g., in car batteries, paint and fuel. However, the use of lead for industrial and energy purposes is bound to economic and political decisions. In this sense, 'it is striking that the very things that we are interested from an explanatory point of view - interdependence, connection, and emergence - have to be treated as troublesome for many quantitative techniques' (Sayer, 1992, p. 114). Notwithstanding the value of biomedical information on air

[15]For further information on the effects of lead on child health see Brown *et al.*, 1990; Schneider and Lavenhar,1986; Wilson, 1983; Needleman *et al.*, 1979; and Caprio *et al.*, 1975.

pollution and ill-health, 'scientific' research does not consider the historical and political structures of society as in any way problematic. In this way, the biomedical approach to air pollution and child ill-health has systematically obscured the societal dimensions of the problem.

2.5 Sociological Explanations

> *There exists a danger that an environmental discussion conducted exclusively in chemical, biological and technological terms will inadvertently include human beings in the picture only as organic material ... It runs the risk of atrophying into a discussion of nature without people, without asking about matters of social and cultural significance (Beck, 1993, p. 24).*

The sociological approach to ill-health and atmospheric pollution focuses on the effects of social class, other parameters of social inequality and government institutions on the state of health of the population (Jolly, 1990; Blaxter, 1990, 1981; Edgar *et al.*, 1989; Dawson *et al.*, 1969; Spence *et al.*, 1954). One outstanding feature in the sociological approach is that the distribution of welfare in society is not conceived as something which flows from the innate properties of individuals but rather from the social structures. Three foci can be distinguished in this literature and at times, they intertwine with each other: the role of social class in determining ill-health; household income and ill-health variation; and the importance of other socio-economic parameters, such as housing, health care provision, family structure, and also individual habits and lifestyle, on ill-health.

2.5.1 *The Role of Household Income in Health*

This view focuses on the dominant influence that household income exerts on health status (e.g., Jolly, 1990; Hicks *et al.*, 1989; Dougherty, 1988; Townsend *et al.*, 1988; Dougherty, 1986). Income may allow, or disallow, access to medical care and to other basic components of good health. However, household income is not available in clinical data. Nonetheless, there is strong evidence that people on low incomes suffer more ill-health. In the USA, the health status of the poor is far below that of other income groups (Miller, 1985; Hicks *et al.*, 1989).[16] The USA National Center for Health Statistics estimated that in 1980, more than 29 million Americans (14.9% of the population) were in a low per capita household-income category. In this group, there were twice as many people limited in their activities because of chronic health problems (29.3%) as the average for members of households of all incomes (14.5%), and over three times (8.7%) as many as the percentage in households with annual incomes of over $25,000 - i.e., the federal poverty level. Members of low-income households experienced almost twice as many bed-disability days per year (13.2%) as the average for members of all households (6.9%) and nearly three times the amount for members of over $25,000 households (4.5%) (Dougherty, 1988).

Turning to Canada, Dougherty (1986) calculated that the overall aetiologic fraction of poverty, or attributable risk percentage of the mortality rate is 30%. That is, 30% of the child mortality in low income groups is attributable to their poverty. Jolly (1990) ascertained a significant increased mortality rate for most age groups, and for the younger age in particular, for the lowest income group. The Australian case corroborates the above findings. Hicks *et al.* (1989) found evidence of 'a relationship between low socio-economic status and the poor health of children, as well as a link between low status and inferior health care' (p. 92). Moreover, in the some country, the rate of prenatal mortality is historically very low, among the lowest in the world. Nonetheless, it remained the case in the 1980s that perinatal mortality was worse for single mothers (who are generally poorer) and for households at the lower end of the socio-economic status scale (Hicks *et al.*, 1989).

However, the unreliability of employing either household income or social class as sole health indicators must be emphasized. For example, in all classes,

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[16]In the USA, mortality rates are calculated in combination for racial, sex and age groups. It is therefore impossible to derive the actual death incidence for the lower income groups alone. Nonetheless, the overall mortality rate is higher for Blacks and other minority groups, most of whom concentrate in the poorer stratum, than for Whites (Dougherty, 1988).

owner-occupiers have lower mortality than those paying rent (Townsend *et al.*, 1988). But these findings point at correlation rather than cause. The growth of absolute levels of resources, the spread of employer welfare benefits and of social service benefits, as well as the increase of owner-occupation among the working class makes a measure of resources all the more important. Income is a nearer measure.

2.5.2 *The Role of Other Socio-Economic Factors on Ill-Health*

This approach looks into further conditions in the household and attributes ill-health to these. Harlap *et al.* (1973) and Leeder *et al.* (1976) claimed that the risk for infants and children of becoming ill increases as the number of children in the household rises because infections are more likely to be introduced into larger households. Another explanation offered for increased levels of ill-health is that mothers of large households are less likely to have their children immunized against measles or pertussis (Butler and Golding, 1986). Illnesses have been shown to occur much more commonly in infants born to households which had several other children already (Leeder *et al.*, 1976).

Housing has been an important focus in the sociological literature. For example, in the UK, inequalities of housing and health are still linked in spite of the dramatic expansion of state housing after the Second World War (Black *et al.*, 1980). Council tenants were found to be 'less healthy' than owner-occupiers, and their unfavourable health records were primarily connected with material deprivation (Townsend, 1979). In West Belfast, marked differences were found between the self-reported health of tenants living in 'good' as opposed to 'bad' council housing areas, allowing for social class, age, smoking and drinking habits (Blackman *et al.*, 1989). However, Golding argues that living in new, centrally-heated houses is not always healthier than living in older, unmodernised dwellings (1986). Two studies, one in America (Spivey and Radford, 1979) and the other in South Wales (Yarnell and

Leger, 1977) have shown a higher rate of illness among children residing in newer public council housing compared with those in older private housing. Not surprisingly, the condition of dampness in the house was found to influence the level of respiratory/bronchial symptoms, and greater incidence of headaches, diarrhoea and aches and pains have been reported among children in damp dwellings than in dry ones (Hart *et al.*, 1986).[17]

Family structure, although only rarely included in present studies, has attracted the attention of some researchers. For example, Blackman *et al.* (1989) claim no significant difference in the health of the children of single-parent households compared with two-parent households.

In summary, existing research strongly suggests causal relationships between socio-economic deprivation, poor provision of medical care, and increased risk of chronic sickness and premature death. But moving beyond strongly suggestive statistical associations to the attribution of causality is hampered by the lack of adequate theoretical models of the causal mechanisms involved (Benton, 1991). Inequality is difficult to measure and trends in inequalities in the distribution of income and wealth, for example, cannot yet be related to indicators of health, except indirectly (Townsend *et al.*, 1988). Additional consideration of a structural nature is thus necessary and will be discussed below.

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[17]Mould growth could be responsible for the significantly worse health of children in damp houses. Spores germinating under moist conditions may enter the respiratory tract, causing bronchial and asthmatic symptoms including fever, tiredness and lethargy. Children then have less resistance to the allergens and are more vulnerable. In addition, allergic reactions may occur to the house dust mites and storage mites that multiply in damp conditions. The mycotoxins, or mould given off by fungi, may get into the mouth or nose and be swallowed, causing stomach upsets as well (Hart *et al.*, 1986).

2.5.3 *Social Class Analysis and Ill-Health*

There is no longer much argument that, in general, those groups of low [socio-economic status], poor urban environment, unskilled occupation and under-resources are likely to suffer earlier from greater morbidity (Blaxter, 1981, p. 109).

The relationship between social class and the structures that deliver health care and ill-health has been documented for the UK where there is a long tradition of classifying the population according to occupational positions. This approach has found that mortality tends to rise inversely with falling occupational rank or status for both sexes and at all ages. In looking at the causes of death for different age groups where differences between the classes are at their greatest, it is therefore particularly difficult to deny the relevance of socio-economic variables (ibid., p. 21). A main argument in the sociological literature is that social class differences in morbidity and mortality are very pronounced with a class 'gradient' and poverty being historically associated with respiratory ailments and vice versa (Blaxter, 1990, 1975; Black *et al.*, 1982; Hart, 1975).[18] Social class is a summary indicator of social inequality which has its origin in social institutions which are outside the individual's control. The basis for ascribing social class is the level of occupational skill: I- Professional; II-Intermediate; IIIN-Skilled non-manual; IIIM- Skilled manual; IV- Partly skilled; and V- Unskilled.[19]

Researchers such as Hart (1986), Fox *et al.* (1985) and Blaxter (1975) have pointed out that health inequalities in England specifically among children emerge as particularly marked among different social groups. At birth and during the first month of life the risk of death in households of unskilled workers is double that of professional households. For the next eleven months of a child's life this ratio widens

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[18]The *Black Report* (Black *et al.*, 1982) is undoubtedly one of the most important and authoritative documents on health and social class produced in the UK since the establishment of the National Health Service in post-war Britain.

[19]On the basis of figures drawn from the early 1970s, men and women in unskilled manual occupations, or in class V, had a two-and-a-half times greater chance of dying before reaching retirement age than their professional counterparts in occupation class I. Even when allowance is made for the fact that there are more older people in unskilled than professional work, the probability of death before retirement in the unskilled group is still double (Black *et al.*, 1982).

still further, 'for the death of every one male infant of professional parents, we can expect almost two among children of skilled manual workers and three among children of unskilled manual workers. Among females the ratios are even greater' (Black *et al.*, 1982, pp. 50-51). Socio-economic inequalities encountered during childhood persist so that ill-health is worse, and death rates higher at every stage of life the poorer the person is (Black *et al.*, 1982; Blaxter, 1975). Earlier large-scale studies by Spence *et. al.* (1954) and Dawson *et al.* (1969) (the Newcastle, UK, 1000 Households survey) of medical consultation figures assembled by occupational class and by health condition revealed high levels of illness, incidence of severe respiratory disease, total days of illness, and medical consultation for serious respiratory disease that were at conspicuously higher rates for the lower occupational classes. High proportions of severely asthmatic children were found in semi- and unskilled manual households (Dawson *et al.*, 1969). Availability of medical care in poor industrial areas in the UK decreases proportionally to need (Black *et al.*, 1982).

Health inequality from this perspective is a measure of the social environment and its capacity to generate inequalities of welfare and survival (Hart, 1986). Hart argued that the population is served in an inverse manner to their needs. In areas with most sickness and death, general practitioners have more work, larger lists, less hospital support and inherit more clinically ineffective traditions of consultation than in the healthiest areas; and hospital doctors shoulder heavier case-loads with less staff and equipment, more absolete buildings and suffer recurrent crises in the availability of beds and replacement staff. 'These trends can be summed up as the inverse care law: that the availability of good medical care tends to vary inversely with the need of the population served' (Hart, 1975, p. 86).

In 1993, deprivation and ill-health were still associated, a premise confirmed by Sir Douglas Black (Mill, 1993). The use of better indices of social deprivation including geographical measurements, such as mechanisms for studying areas by postcode or municipal wards, has obviously enhanced the information but without altering the overall result. Mortality rather than morbidity rates are considered as the 'best available indicator of the health of different social, or more strictly, occupational groups' (Black *et al.*, 1982, p. 63).

2.5.4 *Limitations of the Social Class Focus*

The study of ill-health and exposure to environmental pollution accounting for occupational social class is clearly very helpful to advance the understanding of this relationship. The sociological approach has uncovered substantial differences in health state and these reflect the prevailing social class division and institutionalized unequal distribution of welfare in society. There are, though, a number of difficulties. Social class in the strict sense of occupational status itself cannot cause disease, but acts as a marker for differences between groups of people, including housing, income and education, use of health services, diet and incidence of stressful life events (Golding, 1986). Indeed, 'significant as social class is, it is not a sufficient explanation' (Black *et al.*, 1982, p. 131). It is the contention in the thesis that the analysis of social structures is necessary for understanding health variation in any sample population. It must be done, however, with a few reservations in mind and this will provide a more critical understanding of health variation in urban polluted environments.

First, historically, occupational status has been defined in a gender-biased manner.[20] Most precisely, the male head of the household has been selected as the principal indicator of social class. In the most widely used measures of social class, including that of the British Registrar-General, men are assigned a social class directly on the basis of their occupation, but women and children are only assigned occupational-based class as a result of their membership of a household headed by a

[20]While the use of the term 'social class' can yield information which is useful to the debate about how ill-health is produced, it is equally important to understand that it is a designation introduced by nineteenth-century statisticians. It was initially intended to describe cultural as well as occupational differences between individuals. The concern here was to find a way of differentiating people by social class which would in the aggregate, produce a picture of the different social classes having the greatest mortality differentials possible (Marfarlane and Mugford (1984), cited in Oakley, 1992).

man. This has obvious ramifications when attempting to examine the health of children in single-parent households. In the context of the current research, which focuses on the health of children, there are therefore considerable limitations in attributing causality only in relation to social class:

> *'Social class' might be predictive of life chances, but it is about the lives of men and not necessarily of all members of the household (Oakley, 1992, p. 6).*

Second, in the sociological approach, health stattus is determined almost exclusively either by social relations between groups defined primarily, and almost exclusively, in terms of the ownership (or effective control) of the material conditions in which they live. Such determination leaves out other essential contributors to ill health such as outdoor air pollution, family structure or residential location, any or all of which may not be directly related to social class, as the thesis shows. 'Under the guise of a methodological division of labour between the concerns of sociologists and natural scientists, structuralists exclude the environmental issues themselves from investigation' (Benton, 1994, p. 46). Current 'social class' perspectives thus suffer from a narrow focus, but this can be partly overcome by examining the specific conditions in the household and their relationship to child health.

Third, the debate on health and inequality has drawn principally on mortality rates and access to care. However, inequalities in health may not be the same as inequalities in death. There has been some suggestion that morbidity differences between social classes or income groups are less marked than mortality differences. On the other hand, 'there is evidence that social class trends in the experience of chronic illness, or in the proportion of people who assess their own health as "poor", are steeper than class differences in mortality '(Blaxter, 1990, p. 7).

In conclusion, within the sociological approach to health and the environment, scientists have acquired a vast knowledge about the influence of social class and health institutions on disease, yet is not always clear, however, what aspects of social class are actually associated with the status of health:

> *It is hardly surprising that occupational based class does differentiate. What social class differences do not do is to explain anything. The 'reification' of the analytical construct of class into something substantive-in-itself diverts attention from the ways in which the social and material circumstances of individuals provide different constellations of risk (Oakley, 1992, p. 5).*

2.5.5 *Contextualizing Socio-Economic Explanations of Environmental Illness*

The sociological approach alone cannot cover the whole issue of environmental degradation and ill-health for two reasons. First, neither the structures of social class, owner-occupancy, household income, or provision of health care may satisfactorily explain the incidence of ill-health in a high-income population. Second, the micro-structural level of sociological enquiry, although necessary, narrows the scope of the analysis to the local structures without being able to integrate them as part of a more general social context. Therefore, to approach the relationship between socio-economic circumstances in the household and ill-health, it needs to be framed in a wider political and economic context. A basic argument is that the operation of a capitalist system creates contradictions between health and the economy and that the health problems are not independent of the world of production (Navarro, 1986, 1976; Doyal, 1987; Jones and Moon, 1987; Eyles and Woods, 1983; Illich, 1975).

The view maintains that the processes of commodity production itself will affect health in a variety of ways: the physical repercussions of shift-work, de-skilling, overtime or the use of dangerous chemicals. Yet commodity production also has more indirect effects on health, and the physical effects of the production process extend beyond the work-place. Damage to the surrounding environment and pollution of various kinds are often the by-products of industrialized production (Doyal, 1987).[21] Navarro (1986) has pointed out that health problems exist because of and are

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[21] Doyal suggests that commodity production may damage health through the nature of the commodities themselves, 'if it will sell, then its effects on health are likely to be of little concern to the producer, so

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reproduced by the process of capital production, expand and affect the world of consumption as well, becoming the problems of everyday life. The toxicity of the work environment is replicated more and more in the living environment of the community with outdoor air pollution becoming a remarkable health hazard. Indeed, one of the highest rates of cancer mortality in the USA in the 1970s was registered in Baltimore, Maryland, one of the most industrialized cities in the nation (Radford, 1976). Furthermore, between the years 1979 and 1989, in two out of six US cities studied, Steubenville, Ohio, and St. Louis, highest mortality rates correlated with highest annual concentrations of industrial and other sources of air pollution (Dockery *et al.*, 1993).[22]

It is essential to be aware of social processes, but in the case of environmental issues reliance on this approach in isolation has the consequence of excluding from the political and economic context any consideration of the 'objective conditions' which give rise to environmental concern. Thus, if it is ultimately profit rather than a concern to improve the general population's living standards which is historically the most important determinant of economic and social decision-making, this will be reflected in various ways in patterns of environmental quality and of health status. Significant outcomes which result from economic growth involve, to a greater or lesser extent, the destruction of nature and severe deterioration of human health. Yet the nature and extent of that destruction will reflect the priorities of the society in which that production takes place, 'beneath the concern for the environment there is, therefore, a much deeper conflict involving fundamental issues about the kind of society we wish to create in the future' (Newby, 1991, p.2). Redclift points out that the costs of

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that many health-damaging products will continue to be made simply because they are profitable' (1987, p. 25).

[22]Friends of the Earth (1995) has rightly suggested that health problems due to environmental pollution have been consistently underestimated. However, the reasons offered for explaining the problem focus almost exclusively on the inability of the government to understand the exact nature of the problems, the lack of adequate data, and the type of the medical community's response to a potential problem (i.e. wait and find exactly what it is, before taking action) with the governmen' being held responsible for fostering a type of narrow focused economic growth (ibid., p. 22).

environmental degradation and its distribution are such that continued growth becomes unacceptable. Long before it becomes physically impossible to grow economically, it becomes socially undesirable to do so (1988). Therefore, environmentally related ill-health can be interpreted as an unwanted social cost of present economic growth trends.

2.6 Spatial Literature and the Aetiology of Ill-Health

Even though concrete studies may not be interested in spatial form *per se*, it must be taken into account if the contingencies of the concrete and the differences they make to outcomes are to be understood (Sayer, 1992, p.150). The spatial literature on ill-health and the environment can be divided into three branches: medical geographic; residential location and ill-health variations; and social structures and spatial variations of ill-health and the space matters debate.

2.6.1 *Medical Geography*

'Disease ecology' is the main tradition in medical geography that attempts to elucidate the social and environmental causes of ill-health following patterns of spatial distribution of disease (Jones and Moon, 1987). Such work is closely allied to epidemiology (~~Jones~~ Eyles and Woods, 1983) and may compare the health and disease of groups defined by household composition, inheritance, experience behaviour and environment (Morris, 1975).

Large-scale geographical and correlation studies are useful epidemiological techniques (see e.g., World Resources Institute, 1988; Pyle, 1979; WHO, 1979; McGlashan, 1972). Those conducted by Howe (1975), for example, concluded that the most striking feature of the regional distribution of chronic bronchitis is that consequent mortality in the UK is about 30 times greater than in the USA and five or six time greater than in most of Western Europe. However, the very scale on which these geographical surveys take place limits their value in the study of risk factors that are widely distributed, and implies that they are unable to detect risks associated with environmental factors that are spatially localized (Cuzick and Elliot, 1992). Importantly, studies of cancer mortality suggest, first, that the use of large areas may mask the presence of aetiologic factors in the local environment (e.g., increased incidence of childhood cancer in the vicinity of nuclear installations; see Gardner, 1991, 1989; Shleien *et al.*, 1991; Gardner *et al.*, 1990); and, second, that the arbitrary selection of 'boundaries' to categorize proximity - where the non-exposed are misclassified as exposed - can be highly influential on the results obtained (Hatch, 1992). Thus, disease incidence affected by proximity to industrial plants that emit potentially dangerous chemicals or radiation into the air cannot be studied in this way.

Small-scale geographical studies are more useful. One of the earliest such medical geographic studies and still the most famous example of associative studies on the small-scale is that of John Snow in the 1850s. Snow, who was a physician, plotted the distribution of cholera deaths in London and discovered that the vast majority had lived in one area. He showed that most deaths occurred among those who drank water from one specific pump; and highly condemned the Southwark and Vauxhall Company's water supply (Eyles and Wood, 1983; Blaxter, 1975). John Snow's single-dot distribution map of cholera deaths in London and Howe's early maps (1963) to illustrate the distribution of a number of diseases in Britain are often cited as models which proved the method's usefulness (McGlashan, 1972). From his maps of bronchitis mortality Howe deduced that regions of high mortality in the UK corresponded to areas of dense industrial population. Lunn *et al.* (1970) and Girt (1972) pointed out that air pollution, which may be a characteristic of British industrial cities, is clearly implicated as an important factor in childhood respiratory disease, and in chronic bronchitis in general. Small-scale geographical associations were found between mortality from cancer of the respiratory tract and heart disease in Houston, USA, and regional air pollution samples (MacDonald, 1976). Caprio *et al.* (1975) showed that rates of excessive lead absorption in children are related to proximity to urban roadways and traffic volumes. This type of study has obvious importance and provides clues for further investigations because location is contingent on other factors.

2.6.2 *Residential Location*

Much research has been carried out on the association between area of residence and health (see e.g., Blaxter, 1990; Britton *et al.,* 1990; Gardner *et al.,* 1990; Sobral, 1989). This literature focuses on features of local areas which might damage health. Although ostensibly about geographical area variations in health, many of these studies are not, *per se,* about the role of areas in influencing health; rather they use areas as vehicles for exploring hypotheses about the role of physical exposure or material deprivation in the etiology of ill health (Macintyre *et al.,* 1993).

A main premise in this literature is that over and above individual level attributes of deprivation, people of low socio-economic status may have poorer health because they tend to live in areas which in some ways are health damaging (Blaxter, 1983; Haan *et al.*, 1987). Colley and Reid (1970) suggested a consistent class gradient of frequency of chest conditions with air pollution in urban and rural environments in England and Wales for the children of social class IV and V only. Girt (1972) claimed that people with low income and low occupational status tend to live in the most polluted areas of town not only because of the proximity of the factory and poor cheaper housing but because of the spatial concentration of small-working class houses - featuring poor construction, damp and overcrowding. Sobral argues that in São Paulo, a pre-eminent Brazilian industrial city, the prevalence rates of respiratory diseases were higher in the areas with higher pollution levels, particularly in the slums (1989).

However, the argument that poverty and illness tend to cluster and to reinforce each other confuses causality for two reasons. First, air pollution contaminates not only low income areas. This is due to the power of pollutants to affect areas far from sources of emission; to mix and create new pollutants with new properties; and to the widespread character of polluting activity, such as car mobilization and nuclear plants. Access to better living conditions, such as food, medicine and housing, may offer an apparent 'solution' to health problems posed by air contamination. While not denying their contribution to better quality of life, solutions of this type alone may only mitigate, rather than eradicate, air pollution and health problems because of both the pervasive character of pollutants and the increasing amount of emissions in large cities in particular (see section 2.2). Second, a debate founded only on ecological and geographical features of residential area ignores the fact that social relations of production create and foster such geographical variations, some for their own ends, and that while each area is unique, it also fits a pattern of visible, and less visible, global environmental degradation. Therefore, while not denying that environmental risks may be in a great sense democratic (Beck, 1993), environmental pollution needs to be framed within a clear historical context.

2.6.3 *Spatial Relations and Social Sructures*

The perspective of the third body of spatial literature, and the one adopted in this thesis, is the connections between the social and the spatial. Starting from the premise that production is distributed and organized systematically over space and that, in a fundamentally capitalist society, the system's rationale is the pursuit of profitable production, this approach attempts to clarify the way in which spatial inequality is both produced and used by firms in their search for conditions favourable for profitable production and continued capital accumulation (Massey and Meegan, 1989).

Whilst geographical views of the 1960s claimed a purely spatial word, devoid of substance or content, the 1970s saw the underestimation of geography as distance and in terms of local variation and uniqueness (see, e.g., Gregory and Walford, 1989; Duncan, 1989; Massey, 1987) . However, there are no such things as purely spatial processes, there are only particular social processes operating over space. Neither is the spatial a pure social construct which deprives geography of its spatial role. Space should not be viewed as an absolute entity somehow separate from the material objects located 'within' it. But it is also the case that space cannot be merely reduced to such objects (Urry, 1987). Space is a social construct but social relations are also constructed over space, and that makes a difference (Massey, 1987). This approach highlights the fact that 'space' is not a passive surface on to which the relations of production are mapped, nor yet simply a negative constraint (in the sense, for instance, of distance to be crossed). The fact of spatiality is an integral and active condition. In relation to production, spatial form and spatial strategy can be an active element of accumulation:

> *The challenge is to construct an approach which is neither detailed description and empiricism nor a 'mechanistic Marxist' insensitivity. It is possible both to recognize specificity and to situate it within the grander historical movements of capitalist societies (Massey, 1987, p. 70).*

It is clear that spatial location in itself does not explain the incidence of ill-health because place *per se* cannot make the events happen. The fact that 'the drunk might possibly have chosen alcohol as the common factor and hence as the cause' and that [it] 'is not merely that alcohol was a common factor but the pre-existing knowledge that it has a mechanism capable of inducing drunkenness' (see section 2.4) indicates that non-observable social and biological structures and mechanisms construct spatial location. Moreover, space determines living conditions. The crucial role of spatial relations can be highlighted by paraphrasing Pratt 'space is no longer just "context" or "contingency"; it is - in its reconceptualized social-spatial mode - something that is constructed by and, in turn, constructs, social conditions' (1994, p. 205).

An assessment of geographical patterns of ill-health is necessary in order to reveal the prevalence of disease and possible environmental associations. However, structures and mechanisms underlying these particular variations are more important from a causal point of view. The fact that social processes take place over space, the facts of distance, or closeness, of the individual atmospheric character of specific places - all these components are essential to the operation of ecological and health processes. 'Just as there are no purely spatial processes, neither are there any non-spatial social processes' (Massey, 1987, p. 52). Duncan points out that, clearly, it is not spatial location *per se* which accounts for variations, for 'spatial relations are still secondary and contingent, even if primary, generative causal mechanisms are spatially bounded' (1989, p. 135). In empirical research on concrete objects and processes, analysis of the situation regarding space involves investigating the actual workings and effects of mechanisms in contingent circumstances. As Sayer (1992) points out, it is important to take into consideration that in social systems we have both a greater degree of context-dependence and a continually changing jumble of spatial relations, not all of them involving objects which are causally indifferent to one another. Not surprisingly, regularities are at best transient and spatially limited.

Depending on the nature of the constituents, their spatial relations may make a crucial difference. Spatial contingency will be influential on how social and physical processes work and what forms result. Space clearly makes a difference (Duncan, 1989; Sayer, 1985; Massey, 1987). For example, if smelters are placed near residential areas, lead emissions will most probably adversely affect children living nearby whereas children living at a distance will not be affected in the same way. Sayer claims that a considerable amount of social research is weakened by largely unnoticed scrambling of causal forms; at worst the degree of abstraction from the actual forms in which objects relate is such that the processes by which mechanisms produce their effects are simply obscured and become lost in an aggregate, 'de-spatialized', statistical soup, 'the less explanations of actual events take account of the contingencies of spatial form, the less concrete they can claim to be' (1992, p. 151).

In summary, it is invalid to ignore the fact that physical mechanisms, structural and historical processes and social relations take place over space and in a geographically-differentiated world. Therefore, the study of spatial variation of ill-health and of air pollution is an essential dimension when explaining the relationship between the two. Nonetheless, to say that geography matters is not to say that space alters the processes themselves, although spatial relations crucially contribute to empirical variations. Spatial patterns are not independent of social and biological processes, nor does space determine behaviour. Social and spatial changes are integral to each other.

2.7 The Political-Economy Debate on the Environmental Crisis

Parallel to that on spatial, socio-economic and biomedical dimensions of environmental changes, a debate has developed on the relationship between environmental degradation and economic activity. This debate has emphasized those aspects of modern society which are related to the diverse manifestations of environmental problems and has promoted different solutions between modern society and nature as its sustenance base. The debate focuses on scarcity in nature, the effects of industrialization, sustainable modernization, and the role of capitalism as the main cause of the environmental crisis. The section will first examine the limits to growth thesis. Second, it will discuss views which consider that environmental degradation originates in the sins of industrial expansion. It will then assess the approaches which propose sustainable growth. Here economic growth and technological development are seen as compatible with and sometimes even a condition for maintaining the sustenance base and ecological quality of the planet, rather than the main cause of environmental destruction. Theories of coevolution and risk society are then briefly reviewed. Finally, it will examine the approach that sees capitalism as the main social process underlying the environmental crisis. The current global context of capital accumulation in relation to industrialized cities will be addressed and environmental pollution will be situated within this theoretical framework.

2.7.1 *Natural Limits to Economic Growth*

Researchers of various leanings have emphasized the existence of limits to growth set by the finite stock of non-renewable resources and the capacity of the atmosphere, earth and oceans to absorb the burdens of production and pollution now being imposed upon them. The environmental crisis, on the global scale, has been depicted as essentially a scarcity problem concerned with too many consumers placing an unacceptable burden on a declining resource base, with the 'limits to growth' thesis of the Club of Rome most prominently representing this standpoint (Meadows *et al.*, 1972; Forrester, 1970). Technology is seen as the solution for the devil it creates. Trends of global concern were described as accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment which poses a fundamental threat to the 'carrying capacity' of ecosystems (Ehrlich and Ehrlich, 1970; Meadows *et al.*, 1972; Commoner, 1972; Hardin, 1977).

Dobson (1995) argues that there are three principal features of the limits to growth message which can be recovered and have been adopted by radical Greens. Techonological solutions cannot help realize the dream of infinite growth in a finite system; the exponential nature of that growth both finds its unsustainability and suggests that the limits to growth may become visible more quickly than we might think; and the immense complexity of the global system leads Greens to suggest that our present attempts to deal with environmental problems are both clumsy and superficial (Dobson, 1995, p. 78).

The main critique is that the limits to growth approach reduces the problem of environment and economy to one of scarcity, i.e., to a problem with nature rather than a problem with the social ways of relating to nature, with industrialization, modernization and economic growth. The 'limits' did not themselves call into question the gratification of ever-growing human desires by way of a technologically mediated mastery of nature. This is fundamentally a biological reductionist and deterministic picture of the relationship between environment and society 'but it is made plausible by an inscrutable concentration of power, either governmental and/or multinational, over science and technology in both advanced capitalist and state socialist societies' (Benton, 1994, p. 36).

The core assumptions shared by this and the views discussed in the next section are that there is a single-line cumulative growth of scientific knowledge in history, that this knowledge gives rise to a progressive mastery of nature through its application in technology, and that the development of market forces is the means to ensure protection of the environment (Blowers, 1993). The environment is seen as a pool of resource inputs rather than as a complex system that is transformed by development (Norgaard, 1994). Such a view presumes that the characteristic features of human interventions with their environments can be analyzed in terms taken, unmodified, from scientific ecology (Benton, 1994).

In summary, rather than interpreting scarcity as a natural physical limitation, it needs to be located in historical and social contexts (Dickens, 1992). Scarcity in developed societies is not a product of certain levels of taste and consumption but rather deliberately created and manipulated by producers, 'scarcity is in fact necessary to the survival of the capitalist mode of production, and it has to be carefully managed, otherwise the self-regulating mechanism will break down' (Harvey, 1974, p. 272).

2.7.2 *Industrialism, Modernization and Sustainability*

The discussions of modern society, economy and the environment developed in the direction of evaluating the role of industry as the main force behind the environmental crisis (e.g., Simonis, 1989; Porrit, 1984; Singh, 1976; Illich, 1975; Schumacher, 1974). The thesis of industrialism destroying the environment originates in the view of industrial society theory which claims that a new social order based on technocrats and bureaucrats has transcended the capitalist order, and capitalist societies have thus become industrial, post-industrial or post-capitalist (Navarro, 1986). The central assumption is that the development of industry and its impact on society are the central features of modern states (Badham, 1982, p. 2). Industrialism has been called a super-ideology within which communism and capitalism are inscribed (Dobson, 1995).

Two main strands can be distinguished in the debate on the adverse effects of industrialization: de-modernization and environmental sustainability.

The de-modernization thesis was brought forward by such authors as Illich (1975), Gorz (1983) and Bahro (1986). De-modernizers see that the industrial system is highly administered in an ever more centralized hierarchical way. This centralized, hierarchical character has to be analyzed in relation to the technical systems which are omnipresent in the system of production, but no longer adapted to demands of man and nature. Industrial production is viewed as an organizational device that has become widespread, penetrating for example the educational and welfare sectors of modern society (Spaargaren and Mol, 1991). In a more moderate light, industrialism sees that industrialization, which once sustained most economic growth, is no longer able to meet genuine needs while at the same time protecting the rights of the planet, the rights of future generations and of human health. Porrit (1984) argues that the politics of the Industrial Age, left, right and centre, is like a three-lane motorway, with vehicles in different lanes, but all heading in the same direction, 'The very direction is wrong, rather than the choice of any one lane in preference to the others. It is our perception that the motorway of industrialism inevitably leads to the abyss ... ' (ibid., p. 43). The thesis argues that the industrialism approach overlooks the economic and political forces behind industrialization. Embracing various positions on all the age-old political values such as liberty, equality and community, this view does not transcend any political spectrum (Dobson, 1991). Consistent with their analysis of environmental crisis as part of an all-embracing crisis of the industrial systems, de-modernization theorists share the belief that a solution can only be found by partially dismantling the existing systems of production.

Next are the ecological modernization and sustainable development theses which originate from the shift of emphasis in the 1980s - from the need for economic growth to a debate on how to manage such growth (Spaargaren and Mol, 1991). Ecological modernization stands for a major transformation, an ecological switch-over of the industrialization process to a direction that takes into account maintaining the sustenance base in the context of industrialized societies. [23] Sustainable development also is applicable to the less developed countries and tries to include questions of equal development and peace.[24] The sustainable development view maintains that existing patterns of economic development are simply not sustainable in the long term, as determined in the Brundtland Report (Stern *et al.*, 1992). Although the emphasis is on development, and not simply economic growth as measured by per capita GDP, sustainable development calls for a revitalization of global economic growth to alleviate poverty, 'sustainable development involves more than growth. It requires a change in the content of growth, to make it less material-and-energy intensive and more equitable in its impact' (WCED, 1987, p. 52). From this perspective, it is the 'externalities' of growth (particularly, air and water pollution) rather than scarcity that provide the 'limits' to growth (Benton and Redclift, 1994). The focus of the two is

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[23]For details on the theoretical framework for the ecological modernization thesis, which is a variant of the theories of industrial society, see e.g., Janicke, 1989 and Simonis, 1989.

[24]Bartelmus (1994) claims that the idea of effectively merging environmental issues into socio-economic planning and policies is, however, not new.

undoubtedly on the development of the industrial system as such. The capitalist character of modern society is hardly questionned, as capitalism is seen as rather irrelevant to overcoming the environmental problem. The ecological modernization approach sees the historical phase of industrial society and industrialism as central to the development of modern society. The central economic theme of the eco-social switch-over is the ecological modernization of production and consumption cycles by new and more intelligent technologies (Huber, 1985, in Spaargaren and Mol, 1991).

As in the 'limits to growth' approach, the arguments of ecological modernization and environmental sustainability are based on neo-liberal views and understand the promotion of successful market economies as the principal means by which ecological and environmental problems can be resolved. In this view, economic growth, ecological industrialization and government environmental protection complement each other (Elkington, 1987; Pearce, 1989; Pearce, *et al.*, 1991). This view is flawed because the environment cannot be analyzed as a commodity (Jacobs, 1994). Markets fail to allocate environmental services efficiently 'because environmental systems are not divisible, because environmental systems almost never reach equilibrium positions, and because changes are frequently irreversible ..., environmental economics is a contradiction in terms: 'economists address a broad array of issues with only the aid of the neo-classical model ... Is the neo-classical model that robust?' (Norgaard, 1985, pp. 382-3).

With the emergence of the acceptance of the possibility of sustainable growth it was apparent that environmental degradation and social intervention became conceptually more closely linked than in any reductionist and deterministic view (Redclift, 1992). However, the environmental problem on the global scale was still depicted as essentially one of scarcity and management, separating environmental degradation from the basic social relations that made it possible. The advocacy of sustainable development and ecological modernization took for granted the central issue of economic growth as the motor behind development, failing to recognize the effects on the environment: 'the constant reference to "sustainability" as a desirable objective has served to obscure the contradictions that "development" implies for the environment' (Redclift, 1987, p. 2). Capitalist economic growth is the reality that makes human choice less and less possible under conditions of scarcity.

2.7.3 *Industrialization and the Views of Coevolution and Risk*

These are the views that acknowledge the adverse effects of industrialization and stress the particular historical importance of technological and ecological changes. Coevolutionism and risk society are shaped by the recognition that the past century can be characterized as social system coevolution on stock resources and the neglect of environmental systems. Early discussion of environmental issues failed to consider these important aspects of environmental degradation. Norgaard (1994) focuses on how nature is social by incorporating how people have put selective pressure on the biosphere, he identifies an interactive synthesis and equilibrating operations of both natural and social mechanisms of change (Redclift and Woodgate, 1994).

The era of hydrocarbons drove a wedge between the earlier coevolution of social and ecological systems. Capturing the energy of the sun through ecosystem management became less and less important as Western science facilitated the capture of fossil energy. Social systems coevolved with the expanding number of technologies for using hydrocarbons and only later adopted institutions to correct the detrimental transformations this coevolution entailed for ecosystems and ultimately for people. 'Hydrocarbons freed societies from immediate environmental constraints but not from ultimate environmental constraints - the limits of the hydrocarbons themselves and of the atmosphere and oceans to absorb carbon dioxide and other greenhouse gases associated with fossil fuel economies' (Norgaard, 1994, p. 44).

Attention to climate change, for example, unlike the environmental concerns of resource scarcity in the 1970s, was prompted by apparently profligate energy consumption. Coevolution breaks with the supremacy of the paradigm of the nature/society divide because the global reach of environmental problems has been paralleled by important changes in the way the environment is understood (King, 1991).[25] Beck (1993) points out that universalization of hazards accompanies industrial production, irrespective of the place where they are produced: for example, food chains connect practically everyone on earth.[26] Modernization risks possess an inherent tendency towards globalization.

The coevolution and modernization risks views clearly accommodate industrial features and ecological mechanisms in more complementary and social fashion than do the previous approaches. However, the causative powers emanating from specific historical systems of production are not taken into consideration. The outcome is that these approaches are limited as to insight into the political and economic relations of power that fuel environmental degradation as well as industrialization and posit primarily technology and science as the main causes of change.

2.7.4 *Capitalism and the Environment*

The final strand, and the one adopted in this thesis, is the approach which considers that the causes of environmental crisis in capitalist societies lie in capitalism itself, and exposes the international character of present environmental problems. The main themes in this critical political-economy literature are that society is not industrial and composed of individuals but is capitalist and consists of social groups and classes

[25]Changes in the appreciation of phenomena can be traced to the moment of potential cultural movement caught between two alternative paradigms of knowledge, the 'turning point' (Capra, 1983). The turning point was the discovery of the dual aspect of matter and of the fundamental role of probability, a discovery which has demolished the classical notion of solid objects: 'isolated material particles are abstractions, their properties being definable and observable only through their interaction with other systems' (Niels Bohr, cited in Capra, 1983, p. 69). This shift from objects to relationships has far-reaching implications for science as a whole (Oakley, 1992, p. x). In fact, critical realism focuses on this appreciation of phenomena. This is particularly relevant for examining environmental and health issues.

[26]Moreover, risks display a social *boomerang effect* in their diffusion: even the rich and powerful are not safe from them. 'The agents of modernization themselves', says Beck, 'are emphatically caught in the maelstrom of hazards that they unleash and profit from' (1993, p. 37).

(Doyal, 1987; Navarro, 1976; Jones and Moon, 1987). Indeed, a critical political-economy social theory sees the development of capitalism and economic growth in particular as the main problem underlying ecological questions - rather than as providing its solutions - as liberals do. We need the macro-gaze of social structure and not just the micro-gaze of biological individualism 'to provide an adequate explanation of the social phenomenon of ill-health ... Our aim should be not to reduce the social to the individual and explain by biological variations, but the reverse, that is to place and relate the individual and their biology to the social and political context' (Jones and Moon,1987, p. 323). It is in this social context that ill-health is structurally determined. In this way, the relationship between environmental degradation, ill-health and spatial relations can be examined in its totality.

The involvement of traditional Marxism in the contemporary environmental debate has however meant that rather little positive progress has been made in terms of constructing the new concepts and understandings concerning the relation between nature and modern society. Much of traditional political economy theory - at least until the 1970s or 1980s - has tended to underrate the importance of social variability within social (capitalist) structures, limiting appropriate appreciation of the varying ways in which real capitalist societies have accommodated the self-destructive forces and contradictions of capitalism (Dickens *et al.*, 1985). 'Turning from functionalism to Marxism', warns Dickens, 'did not mean that the analogies and dualism between nature and society were finally dropped' (1992, p. 49).

The Marxist political-economy tradition has been concerned, centrally, with explaining the context in which the appropriation of nature takes place. But clearly, stresses Redclift (1984), 'what could not have been predicted in the lifetime of Marx or Engels was that capitalism would pose such a threat to natural resources that the very existence of development would be called into question' (p. 6). Even if well managed, declares this view, it is a fallacy to believe that any level of economic growth is possible without a corresponding degradation of the environment, however limited (Redclift, 1987). Capitalism wrecks the environment through flows of trade, industrialization, investment and aid that encourage the exploitation and waste of resources, pollution and destruction of the ecosystem.

In addition, environmental degradation can be related to the debate of capitalism and modern society which has emphasized the international features of capital accumulation, the undeniable importance of the international division of labour, and the characteristics of global cities. This stance considers that industrialization in certain regions of the world is not an isolated process of extreme local growth or specific national policy; rather it is related to the development of international corporations and the support of national governments. Cities are not discrete and independent entities, but rather interconnected parts of a globally integrated capitalist economy, with many cities fulfilling different roles (Sassen, 1991; Cohen, 1981). In this sense, cities are not islands unto themselves (Feagin, 1988); rather they are situated places greatly affected by capital investment flows within the regional, national, and international contexts (such as the California Silicon Valley technology centre or the Houston Ship Channel petrochemical complex). Houston, for example, provides raw materials, specialized services and markets for many other economies in the world and this role is essential in the international division of labour:

> *Major cities, as the places where this politico-economic specialization is grounded physically, are the cotter pins holding the capitalistic world-economy system together (Feagin, 1985, p. 1210).*

A view of the environment and the economy needs to encompass a number of closely related, but separable, abstract and concrete levels. These are the development of the local economy and the rise of environmental degradation and their relation to the process of capitalism; and the recognition of the local and global dimensions of both the capitalist economy and local environments. The problems in the environment and their anticipated solutions, depend on the level at which environmental processes are specified: local, regional, and international (Benton and Redclift, 1994).

A critical political-economy theoretical perspective recognizes that, in the current historical period, social structures are mobilized by the general laws of capital accumulation and that it is impossible for capital accumulation and economic growth to take place within the global economic system without unacceptable environmental and health costs. A law is not about the concrete phenomenon which we observe, but about one of the forces which produce it. For example, the law of gravity does not explain, unassisted and unmodified, the flight of aeroplanes. Rather it explains one of several constituent forces which determine this concrete phenomenon (Sayer, 1992). General laws, including the general tendencies of capitalism, are about causation, not empirical correlation. The process of capital accumulation is central here, and recognition of its international dimension is basic to an analysis of economic growth and environmental degradation in Houston.

In order to explain the subject of study in its totality, this thesis will integrate arguments of environmental degradation and the economy from the political-economy perspective of social relations. International corporations, for the most part, calculate profit and loss at the firm level; the government plays a crucial role in fostering capital accumulation; this results in major societal costs, such as air pollution at the local level. Therefore, an historical, political-economy perspective which focuses on the role of capitalism and, particularly, on economic growth, is clearly the most appropriate to reach an understanding of the relationship between the economy and the environment, and hence, between pollution and health. In fact, it is within the analytical framework of the international division of labour that we can understand regional economic growth and local environmental degradation, and relate it to the state of health of residents.[27] This is because economic growth, capital accumulation and environmental change are intricately linked (Cherni, 1993a, b).

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[27]A shifting international division of labour is not, in fact, new. For at least two centuries capitalists have expanded operations across state boundaries to exploit raw materials, labour, production sites and overseas markets. In recent decades a new international division of labour has emerged, one that increasingly involves transnational firms investing heavily in many countries and trading goods and services with one another, or transnational firms' subsidiaries trading within the globally extended framework of one large corporation (Feagin and Smith, 1987).

2.8 The Approach

The final section of Chapter 2 establishes the nature of the analysis of the relationship between air pollution and child health and then defines the conceptual foundations of the thesis.

2.8.1 *The Nature of the Analysis*

For an introductory understanding of the nature of the relationship between air pollution in cities, ill-health and economic growth, it is useful to look at some of the key principles because 'if we do not examine the underlying social commitments reflected in the way we come to regard the environment, we are unlikely to understand fully what is going wrong with the environment' (Redclift, 1992, p. 38). The failure to acknowledge both the existence of *a priori* assumptions in available theories, 'that which is normally ignored' (Adam, 1994, p. 94), plus the fact that they may be misleading, emphasize and reproduce a divided view of society. Such a view unquestionably reinforces prejudice about the causes of degraded environments, the origins of ill-health, and the best political and economic tools for dealing with them.

Alone, neither the analyses of the natural sciences nor those of the social sciences are sufficient to explain the relationship between the economy, air pollution and ill-health. While many scientific approaches have not given enough attention to social, economic and political aspects, the social sciences tend to go to the opposite extreme, hardly acknowledging the independent reality of nature - and that of the environment in particular - at all. Economic, biomedical, social and geographical research explain the properties of complex wholes in terms of the parts or units of which they are composed. The nature/society dichotomy interferes in our analysis because 'our modern understanding of nature and development is embedded in the division between natural and unnatural rather than in reality' (Norgaard, 1994, p. 34). Researchers from different scientific fields have failed to enquire into matters of causality that connect essential aspects of the problem. In this way, conceptual frameworks have maintained discontinuity between the environment and society and, inevitably, have misunderstood the nature of both (Dickens, 1992).

My research is clearly in the social sciences but it depends heavily on the biomedical sciences. Nonetheless, it does not rely on their explanatory power. Recognition of the limitations of the methodology and analysis of existing studies, to which the author is nevertheless heavily indebted, forced the search for an alternative historical political-economy approach. While it is necessary to identify the various dimensions and events which lead to both air pollution and ill-health, as the chapter does, it is vital to establish the causal processes that link them.

2.8.2 *Epistemological and Theoretical Framework*

Dichotomous thought has underlain explanatory methods in which the physical is separated from the rest, whether this is the social, political or economic: 'dichotomous thinking forces ideas, persons, roles and disciplines into rigid polarities. It reduces richness and complexity in the interest of logical neatness...' (Sherwin 1989, cited in Oakley, 1992, p. x).[28] Physical objects and substances, spatial relations, non-human animals and plants may be theorized as belonging to the social as objects, conditions and media of social activity. At the same time, they are never wholly incorporated into society, and persist as complex orders of causality which both enable and constrain human social activity in ways which are only partially calculable and predictable. Therefore, in research terms, the recognition of the independent reality of both society and nature is essential (Benton and Redclift, 1994).

[28]Dichotomous thought, argues Figlio (1979) does not originate in science itself, but is constructed and utilized by society. This philosophical assumption can be traced back to the sharp separation of manual and mental work in the Middle Ages, a demarcation which constitutes the metaphysical framework of a mechanistic and separationist science.

The incorporation of a 'weak biological determinism' (Benton, 1989) is thus necessary and 'to say this much *is* to be committed to a naturalistic approach but not necessarily to a reductionist one. It is to be committed to recognizing the *relevance* of evolutionary theory, physiology, genetics and, specially, ecology itself, as disciplines whose insights and findings are pertinent to our understanding of ourselves' (Benton, 1994, p. 40; emphasis in original). Equally important is the recognition that physical and social events are interconnected; and that there are causal linkages between environmental degradation and historical political and economic trends. This acknowlegement contibutes to a resolution of the issue of separation and duality.

Variation over space is causally relevant. Neither empirical nor structuralist studies alone can explain the relationship between economic development, air pollution and ill-health because different processes can produce similar results (a warning for empiricist research) just as the same processes at the structural level can produce different results (a warning for structuralist research) (adapted from Dickens *et al.*, 1985, p. 243). The thesis will show that the logic of the process of capital accumulation articulates with space to generate socio-spatial patterns of production, and subsequent patterns of concrete environmental degradation.

We need to identify a theoretical interpretation of the social relationships in which environmental degradation takes place. This need stems from the research strategy which recognizes that the concrete is something real, but not something which is reducible to the empirical, and that the concrete object is concrete not simply because it exists, but because it is a combination of many forces or processes (Sayer, 1982). In this sense, the real is more than the concrete. Societies are organized along social class and other lines, and structured in terms of social institutions both responsive to and constitutive of the logic of the dominant economic system of production and reproduction.

So many causes of the environmental crisis in cities are structural, with roots in social institutions and economic relations of production, that anything other than a political and economic treatment of the environment would lack credibility. Therefore, the conceptual framework of this thesis has been developed in terms that are familiar to the political-economy tradition. Historical macro-structural processes are integrated for their definitive power to condition social realities and spatial contexts. Micro-structural factors are considered for their relevant impact on the event. The links between the local and the global capitalist economy are relevant here, 'local differences and uniqueness are defined in terms of the interdependence with international relations' (Massey, 1995). In this thesis, research is conceptually informed; the subject of study is seen in its totality and not merely in each of its different segments; and the method is not divorced from the theory.

The state of local environments responds not only to ecological conditions, but principally to historical processes - e.g., industrialization, energy production, urban expansion and economic growth. But, because capitalist processes that affect cities like Houston also operate at an international level, the analytical frame of reference of local air pollution is found beyond the city, that is, within the international economy. In the case of large cities, these places are not islands unto themselves; rather they are greatly affected by capital investment flows within the regional, national, and international contexts (Feagin, 1988). In this sense, the role of any city within the international economy is crucial. In fact, market- and growth-oriented economic activity is a highly influential factor in environmental degradation.

2.8.3 *A Critical Realist Methodology*

The need to establish our philosophical view of environment and society, and to identify the historical processes that define present social relationships, does not supersede the necessity of knowing what actually happened and how the physical mechanisms and social structures work. It is plain that 'theoretical statements on the level of abstract generative mechanisms cannot be expected to account for concrete circumstances, similarly it is clear that statistical correlations do not necessarily - or even often - identify generative mechanisms' (Dickens *et al.*, 1985, p. 245). Theories do not explain empirical situations directly, but rather indirectly in terms of the structures which produce them. In other words, we need to acknowledge the characteristics of the concrete thing. It is the overall contention here that causality in the empirical conjuncture of environmental pollution, ill-health and economic development can be better understood by considering that the social world is constituted not only by the domain of experience of events but also by other observable phenomena and hidden mechanisms or structures (Bhaskar, 1975). Realism is a philosophy of science that serves as a guide to social research (Sarre, 1987). The question of method is of crucial political importance in generating information that can be socially useful, because if research is to produce politically relevant information it must pose its questions and choose its methods in a way which allows answers of the right form to be produced (Sayer and Morgan, 1985). To approach the events, this thesis adopts a critical realist epistemology.[29] To analyze the events, it employs a comparative study.

The realist view of science is that it seeks causal laws to explain observed events, that these causal laws deal with tendencies in objects, and reality is understood through two criteria: a perceptual criterion and a causal one. The essence of realism lies in 'the movement at any one level from knowledge of manifest phenomena to knowledge of the structures that generate them' (Bhaskar, 1979, p. 17)[30] and 'neither objects nor their relations are given transparently; their identification is an achievement and must be worked for' (Sayer, 1992, p. 88).

According to critical realism, social structures and physical mechanisms create necessary (or internal), as opposed to contingent relations. In necessary relations each

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[29]'Critical realism' is the accepted term to refer to Bhaskar's version of realism. By way of short-hand writers have coined this term to refer to transcendental realism, or scientific realism, and the critical naturalistic positions (Pratt, 1991).

[30]For a detailed discussion of critical realism and its approach and response to criticism see e.g., Pratt (1995, 1989), Clcke *et al.* (1991), Sarre (1987), Massey and Meegan (1985) and Bhaskar (1975, 1989).

person is dependent on their relation to the other. In contingent, external, relations an object can exist without the other. It is neither necessary nor impossible that they stand in some particular relation.[31] Some attributes and powers appear to be necessary features of what objects are while others appear to be incidental (Sayer, 1985).

The research in this thesis will focus on the whole subject of study. Nonetheless, to be practically adequate, knowledge has to grasp the differentiation of the world. What is needed is a way of individuating objects, and of characterizing their attributes and relationships. To be adequate for a specific purpose the method must abstract from particular conditions, excluding those which have no significant effect in order to focus on those which do. 'Even where we are interested in wholes we must select and abstract their constituents' (Sayer, 1992, p. 86). The object of study of this thesis is many-sided or 'concrete'; to be understood, the many constitutive elements isolated by abstractions need to be synthesized. What we abstract from are the many other aspects which together constitute the concrete relationship between air pollution and child health. Abstractions neither divide the indivisible nor lump together the divisible and the heterogeneous. For instance, in order to address child ill-health variation, we definitively need to isolate and assess certain components which might affect it, such as socio-economic circumstances of the household. However, explanations would be inappropriate without investigating further aspects of the problem - e.g., provision of health care, levels of outdoor air pollution, and the legislation that controls industrial emissions - which may be relevant to the onset of the concrete event, that is, ill-health.

[31] Necessary relations are not always harmonious or evenly balanced; on the contrary, as is true for state and council housing, they may combine mutual dependence with one-sided domination in terms of the relative power of each element of the relation (Sayer, 1992).

2.9 Conclusion

A number of problems have emerged from the review of current scientific explanations of the relationship between air pollution and child health. Preoccupation with the physical and personal factors, with generalization, and with identification of strictly social structures plays a more prominent role than abstraction. Hence, much of the work in the field of environmental degradation, economy and health has been concerned with establishing universal, regular empirical relationships. In this way, both the interrelationship between physical and social events, and the causal connections of historical economic changes and spatial and social variations, in terms of human ill-health and environmental pollution, have remained not only unresearched but, more often, unacknowledged. Separation between the social and the natural sciences has contributed to mythologizing of the links between environment and politics (Redclift, 1984). Such cognitive assumptions to explain environmental degradation and ill-health have been dominated by a conception of theory based upon the logical positivist and empiricist philosophy of science.

The main verdict on the positivist, as opposed to realist, interpretation of epidemiological and ecological information, despite its logical rigour in assessment, is that it is a fetishist means as far as explanation is concerned. While description and quantification are necessary, these cannot replace causal explanations. Empiricist methods, as tools to approach ill-health associated with air pollution by measuring the extent of the events and their associations, while helpful are not always sufficient.[32] Essential as natural sciences investigations and identification of geographical patterns are, it is difficult to establish causality using the positivist methods alone because the actual connections and interactions between objects have been recorded often in aggregates, or in associations in which the specific individuals or contingent circumstances entering into the relations cannot be identified (Sayer, 1992). Nor can

[32]Positivism should not be equated with quantification which can be applied in any approach (Johnston, 1994).

structural processes underlying the associations be pointed out. While explanation in positivism is often considered to be synonymous with establishing the causes of events, there remains a fierce controversy over whether or not the real world actually behaves in such a manner (Jones and Moon, 1987). There is a weaker concern with conceptualization, for observation is assumed to be unproblematic and description a minor preliminary to the business of science.

Typically, natural and social scientists alike do not regard the presence of supra-processes which are historically determined, that is, capitalism, as in any way problematic. Sociological approaches certainly recognize the effect of social institutions, e.g., social class, but tend to ignore the overall effect of the process of capitalism. Structuralism has remained in the realm of the theoretical, has hardly addressed variation and has avoided acknowledging crucial interconnections between society and nature. Conceptualization of national and international economic processes has been either inefficiently connected to physical and social events or theorization has not transcended the realm of abstraction. Progress towards seeing environmentally related problems as linked to historically determined economic processes has been slow. In this way, scientific explanations of air pollution and of ill-health have remained atomist and ahistorical. Indeed, interpretations of rising air pollution and child ill-health in cities rely - perhaps more than ever - on scientific knowledge from ecology and biomedicine. It is the contention in this thesis that examination of common patterns of economic growth in the past and in current times can prove not only complementary to scientific information, but also crucial to an understanding of the problem.

In summary, most existing explanations of the relationship between environmental degradation and ill-health have focused either on the biomedical, purely social and institutional, or geographical aspects of the relationship whilst avoiding the integration of an analysis of the political and economic dimension. Others have stressed the role of the economy without recognizing the significance of social and spatial variations. This thesis attempts to overcome those limitations by examining biological mechanisms and social structures, by taking into consideration a theoretical recognition of social historical forces that operate in society, and, substantially, by establishing empirical causal relations that link these factors together. In this way the conceptual approach of the thesis is not limited by structuralist or empiricist generalizations. The thesis stresses that the focus on two empirical dimensions of society, that is air pollution in cities and ill-health, is important in itself; it is, essentially, a way to understand better the linkages between capital accumulation and environmental degradation. The critical realist approach is the most appropriate method to address the subject of study. The next chapter moves on to explain the research methodology employed in the thesis.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The overall aim of Chapter 3 is to justify the selection of the city of Houston, its environmental health and the child population as the topics of study of this thesis and to establish a methodology for the examination of the relationship between child ill-health and air pollution. The particular methodology described below was necessary to quantify and explain the events studied. The methodological framework consists in the tools used to elicit and analyze the empirical events and to elucidate their political, economic and physical context. The research methodology aims to avoid either a too partial or a too general view of air pollution and ill-health. A critical realist methodology is adopted here. However, in practice, critical realism does not offer one particular model of research and the research method as applied to the theme of the thesis enriches the practical application of critical realism. Neither have users of the method been explicit about their ways of employing it:

> *The most exciting moment in the development of critical realism should be the attempt to practically work through its implications in order to understand the world. ... A key sticking point in the practical application of critical realism is research methodology (Pratt, 1995, p. 67).*

A more arduous way has been opted for in this research, that of spelling out the methodology in terms of the adopted concepts and development of the research strategy. The methodology entails also the application of the researcher's creativeness and sensitivity to detect and retroduce[1] causal mechanisms and relevant events. The question is which events ought to be examined and what are

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[1]Retroduction is a mode of inference in which events are explained by postulating mechanisms which are capable of producing them. In many cases the mechanisms so retroduced will already be familiar from other situations and some will actually be observable (Sayer, 1992).

the most appropriate ways to address them. This was a complex task since neither air pollution nor child ill-health is homogeneous, equally distributed or a simple phenomenon.

The chapter is divided into five parts. The rationale behind the selection of the city of Houston, health and the child population is first analyzed. Second, the empirical model of causality followed here is developed, drawing attention to the essential dimensions of the relationship that need to be explored. Third, the areas of enquiry and the research design are presented. Three complementary investigations,(i) contextual research, (ii) the household survey and comparative study, and (iii) semi-structured interviews are discussed. These are elucidated within the perspective of combining extensive and intensive research design. The research operation is then explained, including the selection of sample population, the structured questionnaire and the rationale behind conducting a few semi-structured interviews with key informants. Finally, the thesis' four analytical approaches, quantitative, comparative, causal and qualitative, and the combination of analyses are described.

3.2 The Selection of Issues

The core theme of this thesis is the relationship between environment and society, and the objective is to examine the conjuncture of economic growth, air pollution and ill-health in a new, enriched light. In addition to conceptualizing the relationship between nature and society, as set out in Chapter 2, the thesis examines the actual facts in the real world and their contextual background. The investigation focuses on a range of issues which crucially affect an apparently only biological relationship. The selected issues are the city of Houston, health as part of the environmental agenda and as a current social concern, and the child population.

3.2.1 *The City of Houston*

The conceptual framework treats the city of Houston as a contingent urban setting within which the relationship between economic growth and environmental degradation, and the incidence of ill-health are examined. Houston is the epitome of a capitalist 'heaven' and an air pollution 'hell'. Urban growth in Houston illustrates dramatic changes occurring in most metropolitan areas over the last 100 years as a result of developments in the local and international capitalist economy. Because Houston is a microcosm of both economic growth and environmental degradation, it provides a useful case study furnishing significant findings that may be extrapolated to other cities in the world where similar conditions can be identified.

Although there are a number of noteworthy points about the city's successful growth in particular, Houston is certainly not considerably different from other major US cities (e.g., Los Angeles, Dallas, Detroit). First, there has been especially widespread, unplanned and uncontrolled urban expansion and population growth in Houston since the beginning of the century, particularly since the late 1940s (Thomas and Murray, 1991; Shelton *et al.*, 1989; Feagin, 1988; see Chapter 4). Since the 1950s in particular, residential, commercial, and industrial development have extended across both the city and suburban boundaries without any concern for planning land use. Such trends brought remarkable changes to the physical landscape (Thomas and Murray, 1991). These changes have created typical 'American' landscapes, commonly seen in Houston and in other cities: landscapes made to suit vehicular transportation, suburban housing and shopping centres, 'a sameness in commercial strips everywhere' (Jackle, 1994), luxury condominiums which reflect the 'landscapes of private power and wealth' (Wyckoff, 1994, p. 235), and a landscape of 'specialized activity and mechanical integration, of growth and decline, and of abandoned and reused relics' (Meyer, 1994, p. 249). Population growth has been constant since the 1850s. The city stands out as a case of relatively high population gains among other large metropolitan areas in US that have experienced moderate increase or occasional losses over the same period. However, Houston is not remarkable as an isolated case of relatively high population growth in an era of urban decline. In fact, a handful of metropolitan areas (e.g., Phoenix, Tampa-St. Petersburg, San Diego, Denver, Atlanta and Dallas/Fort Worth), in addition to Houston, continued to grow rapidly in the 1970s.

Second, rapid and unplanned economic growth has taken place in Houston. Epithets such as the pearl of the Sunbelt, the capital of energy, the free enterprise city, the oil city, the miracle city, and the space city (because of the presence of NASA) illustrate the particular economic concentration of the city. A colossal petrochemical complex, including refineries and industry, is located in the Houston region with the Port of Houston ranking first in handling US foreign tonnage and second in total tonnage in the 1980s and 1990s (Port of Houston Authority, 1995).

Third, the medical sector of Houston stands out because of its size and quality. The Texas Medical Center in Houston is the largest medical complex in the world and the main employer in the city (Greater Houston Partnership, 1995/1996). Indeed, health care is one of the region's most important 'industries' and the medical facilities in the city are numerous and impressive. Houston is also known for its internationally renowned cancer treatment and research centre, The University of Texas M.D. Anderson Cancer Center, for top medical schools, such as the Baylor College of Medicine, and for pioneering new methods in surgery and heart disease treatment.[2]

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[2]The Texas Heart Institute was the site of the first human implant of the air driven left ventricular assist device and one of the first artificial heart transplantations was carried out in Houston (by M. E. DeBakey).

Despite the idyllic picture of economic growth and medical excellence there are contradictions. First, high levels of air pollution make Houston one of the most contaminated cities in the USA (US EPA, 1991; TACB, 1992; Houston Post, 1990a). Although to some extent Houston resembles other American cities in experiencing such high levels of general contamination (e.g., Los Angeles, Detroit, St. Louis and Chicago), industrial emissions in particular have reached alarming concentrations in the city (see Chapter 4). The key issue is that industrial emission tends to be localized. Hence it is likely to affect health. Indeed, large sections of the city have been frequently invaded by industrial pollution, but the residential areas located nearby petrochemical plants in particular, have been most adversely affected by the emissions.

Second, my research found that access to competent medical facilities offered by the city was extremely expensive, hence the excellence of this sector was available mainly to the wealthy. In addition, the standard of health among the poor residents was poor and their access to basic health care deficient (see Chapter 5). Third, despite the fact that Houston was ranked among the most air polluted cities in the country, and water quality was an endemic preoccupation, neither medical nor political institutions had condemned the insalubrious living conditions of the city. This remarkable fact prompted the researcher's questions not only on environmental degradation versus economic growth, but also, significantly, on the actual protection of public health in Houston.

The thesis argues that the contrast between, on the one hand, wealth, the centrality and strength of the medical sector in Houston life, and on the other, the deplorable state of the environment, poor public health, and their limited institutional protection reflects elemental contradictions of economic growth. In this light, Houston offers itself as an appropriate case study for carrying out field work on the capitalist trends of growth in the city, on the role of the government to encourage both market-oriented economy and health care, and on the institutional protection of the environment and public health. It is the contention of the present study that economic growth and environmental pollution are intricately linked. The view that human progress can only be obtained through economic growth which disregards environmental and human costs has gone largely unchallenged. Unfortunately, increasing environmental degradation and ill-health are often treated as if they were divorced from the dominant type of economic activity, hence the separate analyses of environment, and development (Cherni, 1993).

The thesis attempts to synthesize the different aspects of the pollution problem and to situate it; it shows that economic growth, as part of the process of capital accumulation, implies not only affluence (for some) but also environmental damage and health misery (for most). A main objective is to understand these particular problems and contradictions in Houston in relation to air pollution and child ill-health, and to provide a methodological and analytical approach which can be employed in similar research in other cities.

3.2.2 *Environment and Health*

The case for environmentally related ill-health in particular is selected for three reasons. First, over the last 30 years many investigations, particularly in the USA, have addressed the problem of air pollution and health - most notably, lead contamination in cities. In the last decade, there has been a remarkable rise in this research. In Britain, after at least two decades when the issue went almost unresearched, it has gained renewed attention and is becoming a research priority in the 1990s (e.g. Medical Research Council and Institute of Environmental Health, 1994). The relationship between air pollution and health made the headlines in the UK and other European cities as memories of the pea-soup days returned to London in December 1991.

Second, lower levels of pollution are apparently as hazardous as episodes of extreme air pollution.[3] Adequacy of present pollutants safety standards is certainly questionable. The American Lung Association advises that when ozone concentration exceeds healthy levels, i.e., 70 in the air pollution index, rather than the official index of 100 (see section 4.3), people should not engage in rigorous outdoor activity (American Lung Association, 1994). While air quality is described as good until ozone reaches 90 ppb for one hour in the UK, the World Health Organization's safety limit starts at 76 ppb. It is much the same for benzene, a cancer-causing chemical. While levels up to 5 ppb have been described as 'low' by the UK government, the expert panel on air quality standards has recommended that benzene concentrations should not exceed 1 ppb on average over the year (Lean, 1994a).

Third, human health is one aspect of society which researchers have typically considered as (i) a physical and biological phenomenon, or as (ii) an exclusively institutional, social, or individual matter. As a result, grounded on some sort of association of cause and effect, research on environmental degradation and health has produced useful information but piecemeal explanations, such as the typical simplistic explanation that airways become obstructed due to the effect of air-borne particles. Significantly, the thesis examines the circumstances that link the natural and social dimensions of health, and highlights the influence of historical contexts on the state of health.

Fourth, human health has generally assumed a narrow position within the environmental agenda. Topics such as soil erosion, acid rain, deforestation, nuclear radiation, and climate change have been subject to analytical scrutiny. Human health, however, has received scant attention from environmental researchers, and even less from those who position themselves within a political

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[3]The American Lung Association claims that high-pollution conditions are hazardous to the healthy as well as to the weak or the young. Recent studies have documented increases in coughs and colds among healthy youngsters during high-pollution periods (1994).

economy perspective on the environment. Undeniably, the promotion of healthy urban environments has been advocated since the 1970s.[4] The WHO's project Healthy Cities[5] and the most recent debate on sustainable cities reflect this interest (on Healthy Cities see e.g., Ashton, 1993; Davies and Kelly, 1993; Draper, 1991; on sustainable cities, see e.g., Breheny *et al.,* 1992; Howarth and Norgaard; 1992, Stren *et al.*, Blowers; 1992, Elkin and McLaren, 1991; WCED, 1987).[6] The concepts of Healthy Cities and of sustainable cities correspond mainly with movements underpinned by a post-modern, aesthetic and moral view of health rather than biological or political definitions of illness (Davies and Kelly, 1993). In this context, environment and health have been approached from a limited, pragmatic perspective. In contrast, the thesis attempts to raise the issue of human health to a central position within both the political and economic and scientific environmental agenda.

3.2.3 *The Child Population*

Children within households are the target population in this thesis because their state of health often clearly reflects both the risks posed by environmental pollution, and the effects of household socio-economic circumstance, and social institutions. Furthermore, child health is the main parameter of change in the thesis for three reasons. First, there is increasing evidence to link air pollution with rising child asthma epidemics (see e.g., National Asthma Campaign, 1994; Lean,

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[4]The consideration of urban conditions and the global eco-crisis was introduced in the 1970s with the ecological idea of the healthy city (see Ashton and Ubido, 1991).

[5]The extensive Healthy Cities project began in Europe in 1986 (Duhl, 1986). Despite their supposedly 'ecological' focus, the projects have been pragmatically managed and have concentrated on administrative rather than political aspects of health care. The concern with environmental pollution is only additional to other important aspects of public health (Ashton, 1993).

[6] While the Healthy Cities agenda focuses on public health, the debate on sustainable cities includes a wide range of issues and positions regarding definition, economics and the environment, perceptions and policy for urban sustainability. As to health, practical measures to be taken in prospective sustainable cities range from ensuring institutional health care to good diet, and to preventing air and water pollution, physical risk and mental stress. For more detail on sustainable cities see e.g., Mega, 1996, Nijkamp and Perrels, 1994; Breheny *et al.,* 1992.

1993a, 1993d; Brown, 1992; Hall, 1994) and with other respiratory disease (see e.g., Romieu *et al.,* 1993, 1990; Bobak and Leon, 1992; Boussin *et al.,* 1990; Dockery *et al.,* 1989; Villalbí *et al.,* 1984; Radford, 1976; Collins *et al.,* 1971). Young children are particularly exposed to pollution in the form of traffic emissions, 'now we have pollution actually discharged straight into people's faces - especially small children sitting in pushchairs' (Brace, 1994). Older children may be equally exposed to car and industrial emissions when making their way to and from school. Moreover, children are likely to travel less than their parents, and therefore, child health offers a more accurate study subject when measuring exposure to local air pollution.

Second, that environmentally related child disease has been studied almost exclusively in relation to lead contamination (e.g., Baghurst *et al.*, 1992; Nyhan, 1985; Needleman *et al.*, 1979; Caprio *et al.* 1975). Once atmospheric lead was dramatically reduced in some countries in the 1970s, e.g., the USA, the possible health effect of other toxic materials on children was, shamefully, considered less important. In fact, there are still many air-borne pollutants - equally or perhaps more dangerous than lead, while some have yet to be fully identified - which put child health at serious risk. The thesis examines the effect of air pollution on child health in a city where lead contamination has been practically eradicated, but where, nevertheless, its levels of air pollution are very high.

Finally, both nationally and internationally, child mortality and morbidity rates are documented indicators of social welfare (see, for example, Blaxter, 1990, 1975; Jolly, 1990; Edgar *et al.*, 1989; Hart, 1986; Black *et al.*, 1982; Dawson *et al.,* 1969). US studies show that children are increasingly worse off than their parents' generation in several important dimensions of physical, mental and emotional well-being (Miller *et al.*, 1985; Boone, 1989). The increasing evidence that children are particularly vulnerable to the effects of air pollution raises the issue of an additional socially created threat to children (undeniably, the elderly are also at great risk; see, for example, Médina and Quénel, 1993; Read and Read, 1991; Schwartz and Marcus, 1990). The thesis investigates the dangerous burden that society, through environmental pollution, imposes on child well-being. It measures and analyzes infant mortality and child ill-health in order to provide useful information on the working of social structures at the micro and macro scales to enable relevant changes to be implemented.

3.3 The Causal Model

The purpose of this section is to explain how this thesis determines the course of events in the relationship between environmental degradation and society. It first describes how industrial emissions become hazardous air pollutants, and second, how micro- and macro-structures intertwine with the spatial form, that is, with environmental and socio-economic conditions in particular areas, to increase health risk. The spatial form, to rephrase Sayer, must be considered because explanations of concrete phenomena which abstract from spatial, or other, forms, 'must be regarded as being significantly incomplete. Yet few social scientists even recognize the problem, and this despite the fact that variations in form are a major factor in the failure of causal mechanisms to produce empirical regularities' (1992, p. 247).

As discussed in Chapter 2, the study of air pollution and child ill-health in Houston was carried out bearing in mind that these particular events are the result of political and economic structures. In addition, however, it recognizes that events are also a window to detect the existence of social structures. Ecological and health events are produced by physical mechanisms but are mediated by society. The empirical study draws on the epistemological postulate that the subject of study is composed of natural, political, and economic realities, the methodology on the principles that the events should be adequately contextualized, and the theoretical view on the dominant role of political and economic processes, which are historically determined (see section 2.8).

The first part of the causal model will stress how ecological and health mechanisms may be activated and hints at their interaction. As shown below, and put simply, the thesis maintains that natural ecological conditions as such certainly do not cause environmental contamination in cities. Ecological mechanisms must be triggered to cause air pollution which, eventually, brings about ill-health in the following manner:

1. Certain chemicals if released,
2. under certain conditions,
3. produce certain events: pollution in the environment.
4. Pollution in the environment,
5. under certain conditions,
6. produces ill-health in people (if exposed to certain concentrations for a certain time).

Industrial processes and consumption of energy, motor-vehicle-combustion and other sources release large amounts and a yet unknown variety of chemicals into the environment. Atmospheric concentration of these by-products varies. Although chemical emission is the crucial event in the formation of air pollution, additional factors affect the state of the environment. Three basic physical conditions are required for chemical by-products to degrade the environment and to become health hazards. First, they must exceed the natural capacity of the environment safely to absorb them; next, they must engage with climatic and topographic features (e.g., sunny conditions may precipitate a photochemical reaction if the concentration of pollutants is high; atmospheric inversion may contribute to a pollution event); thirdly, they must combine with other chemicals to produce new contaminating materials. Finally, pollutants may also be found in places far from their sources of emission because it is the property of some materials to spread over large areas and to be displaced. However, the combination of atmospheric, ecological and chemical mechanisms alone may not be sufficient to give rise to widespread environmental degradation and ill-health. One needs to know which technical and also social conditions prevail in a particular moment in history. For example, type and quantity of emitted chemicals, the combustion technology and engine speed, proximity to emission sources, poorly structured institutional protection of the environment (e.g., insufficient air monitoring), lax government policies to control chemical emissions, and inappropriate standard health safety limits may each directly contribute to the degree of chemical concentration. Same conditions may, however, only be expressed in specific areas, affecting a whole range of conditions for the residents, hence the importance of considering variation in order to assess the working of causal mechanisms. Variations in the real world are thus also important for the different damage that these may cause to those residents (see section 3.2.1).

In fact, population exposure while applicable to all, is not applicable in an unqualified or unspecified way, hence the relevance of surveying the population to uncover variation of effects. Social status and spatial location in relation to emitting sources may mediate the construct of the relationship.[7] Air pollution gives rise to environmental degradation and child ill-health follows exposure to pollutants under certain spatial and socio-economic circumstances -e.g., living in the proximity of toxic emissions sources, poor living conditions, deficient health care.

The integration of technical knowledge about amount and type of air pollution 'dumped' into the environment with an analytical view that argues that the existence of air pollution in the first place depends upon the type and extent of

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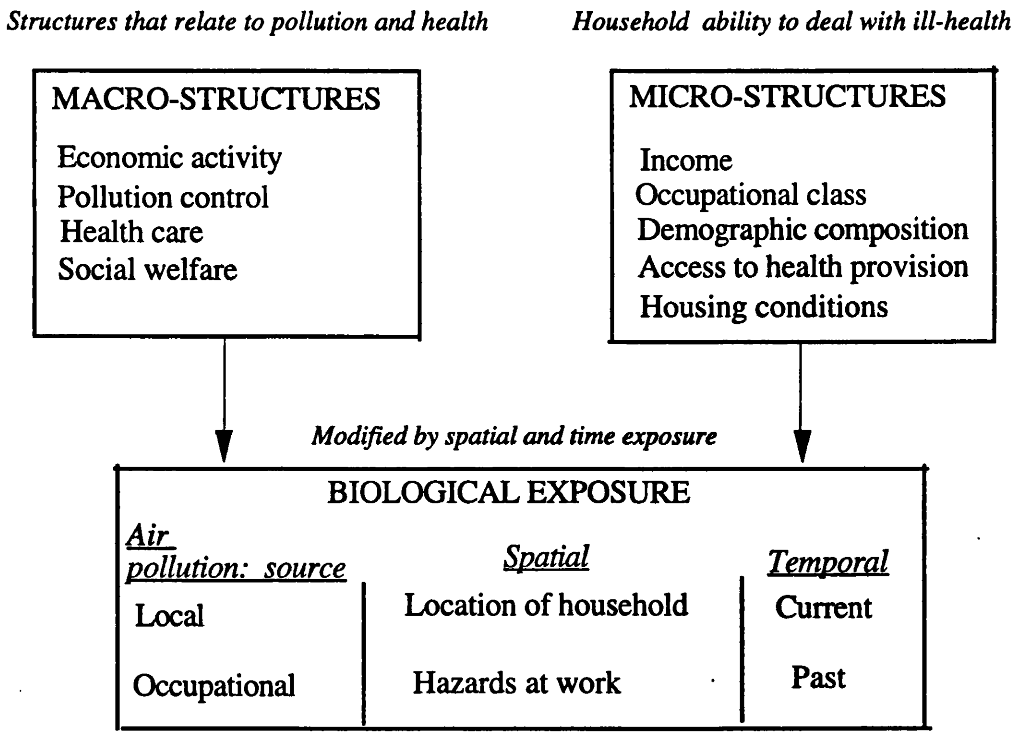
[7] Note that 'proximity' is the most widely used parameter for location. However, previous knowledge of the physical mechanisms of chemicals tells us that industrial pollutants spread, and mix, and may be found in areas other than industrial.

economic activity, and also upon institutional efforts to protect the environment and public health, is essential to explain rising air pollution and child ill-health. In addition, the ability of the population to deal with the environment 'carrying capacity' is relevant in this relationship and this depends on how and where residents live. In conclusion, a tripartite causal model for the examination of air pollution and ill-health is followed (see Figure 3.1). This formulation suggests that there is a connection and continual interplay between social and biological factors. It acknowledges the importance of ecological and health mechanisms in the relationship, recognizes the necessity of assessing socio-economic and spatial variations of the events and stresses that macro- and micro-structural factors are modified by the geographical location of the household in relation to industrial plants, by length of exposure, and by historical levels of air pollution.

Figure 3.1 Model to approach the relationship between air pollution and ill-health



3.4 Research Design

This section consists of three parts. In the first part, the objective of the empirical study, and the research framework of combining extensive and intensive designs are presented. In the second part, the contextual field work and qualitative information are discussed. In the final section, the rationale for the extensive and intensive survey is made more explicit and the comparative study is explicated.

3.4.1 *Areas of Enquiry and Research Framework*

The purpose of the enquiry was to raise questions on the most relevant aspects of economic growth, air pollution and child health in Houston and research questions were compartmentalized in five areas. First, the historical area, where questions were directed to political and economic structures, that is on (i) industrialization and the energy industry in Houston; (ii) governmental environmental protection; and (iii) the US health system and provision of public health care in Houston. Second, the focus was on local environmental pollution. Questions enquired into the historical development of Houston's current environmental crisis, characteristics of air pollution in the city, monitored pollution, residents' report of air pollution and their concerns for the local environment. The overall state of health of Houston residents, the health of children in the study areas, and the characteristics of the studied households in aggregated forms were the third area of enquiry. In this context questions referred to overall public health in Houston, e.g., the city's rates of mortality and morbidity, disease mortality, cancer death and risks, most common disease among Houston children, and reported child ill-health in the surveyed households. Fourth, questions addressed the socio-economic, demographic and location circumstances of the sample households within which child health was examined, e.g., income, occupational class, number of children, family structure and effects of socio-economic conditions. Finally, the interaction between child health changes and rising air pollution was deliberately explored as it varied in social and spatial contexts.

The research questions were applied to the city of Houston. However, there were difficulties. Such an enquiry needed to grasp the general trends as well as particular relations. This is why a mix of extensive and intensive techniques was employed to generate as much essential knowledge as possible in what is a complex research area. Extensive research enabled a more precise description of the empirical data to be reached. Intensive research identified structures and mechanisms into which individuals are locked. Both types of research were important but they fulfilled different functions, the one primarily descriptive, the other primarily explanatory (Gregory, 1986; Sayer and Morgan, 1985). Extensive and intensive techniques were used together. They were complementary and produced quantitative and causal types of information.

The research design consisted of three linked and contemporaneous investigations carried out in Houston, our case study: an extensive large survey of 300 households plus a few semi-structured interviews with specialists in both the medical and environmental fields; an intensive study and comparative study of the same population as the 300 interviewed households but grouped by residential location and socio-economic status (see Appendix A.1); and contextual research in relation to Houston's economic development, environmental degradation and health status (see Table 3.1).

Table 3.1 Summary of the empirical research framework

Research Strategy	Contextual research	Survey	Comparative Study
Research purpose	To explore and interpret city themes To examine social structures and physical mechanisms	To examine extent and characteristics of problem	To establish empirical relations of causality
Focus of data collection	City of Houston	Household Officials and academics	Two geographic areas and two socio-economic groups
Areas of enquiry	Environmental legislation; health system Air pollution monitoring Public health rates Economic growth	a. Child health b. Local air pollution c. Environmental concerns d. Household socio-economy	Variations of child illness in polluted poor and rich areas; in less polluted poor and rich areas
Tactics of enquiry	Extensive documentary Intensive literature	Structured and semi-structured interviews	Intensive statistical control and statistical associations
Type of data	Primary Secondary	Primary	Primary
Analysis of Data	Quantitative Qualitative	Quantitative Quotations	Quantitative comparative Causal

3.4.2 *Contextual Research*

While all the research strategies used in the thesis share the goal of providing evidence about causal relationships (that is, what leads to what), the contextual research in particular was necessary to provide two components, the historical background and the state of affairs in the selected setting, and to identify the biological mechanisms involved.

First, a close examination, analysis and interpretation of primary and secondary data from public record sources and literature was carried out to reveal the economic, public health and air quality performance of Houston since the beginning of the century and particularly after the Second World War. The contextual research was designed to examine city themes. That 'we should study things in context may seem so commonsensical as to be unworthy of mention'

(Sayer, 1992, p. 248), yet, frequently, contexts are merely something referred to in general terms as part of the background to the research. This practice encourages a blindness to scrambling of structures, causal groups and contexts, rendering society atomistic, unstructured and unhistorical (ibid.). Contextual research of the city entailed field-work investigation in the real world (Robson, 1993, p. 52).

The contextual study elicited both crucial quantitative and qualitative information. Contextual research chiefly involved scrutiny of available statistical information on levels of air pollution, economic indicators, population growth, and public health indicators. Documentary and secondary sources were used to investigate past and present environmental degradation in Houston (e.g., AQCB, 1990b, 1988; TACB, 1993b, 1988, 1987; US EPA, 1995, 1990), to assess public health (e.g., City of Houston Health and Human Services Department, 1984-1988, 1990; Dougherty, 1988), and to analyze early and later economic growth (Pratt, 1980; Williamson, *et al.*, 1963; Port of Houston Authority, 1991, 1995; Greater Houston Partnership, 1992). The contextual study also entails examination of historical processes of economic development and environmental degradation in Houston, evaluation of institutional regulations to protect the environment, and assessment of the US medical care system and access to health care.

Exploration of how the current and past context was structured, what is in there, and how the key elements under study fit into it was vital for explaining the findings of the survey. Some of this information was crucial for the conceptualization of questions included in the household questionnaire used for interviewing but even more for the interpretation of data so obtained. Initial information on the city was significantly expanded in later stages of the research.

Second, a comprehensive review and analysis of existent epidemiological and medical literature on the subject of air pollutants and ill-health complemented by literature on pollution in urban settings was conducted. This was undertaken as part of the general approach to the natural sciences.

3.4.3 *Extensive and Intensive Research: The Survey and Comparative Study*

The survey was conducted to provide an original and accurate extensive and intensive picture of the state of child health and of air pollution conditions in Houston (see section 2.8.3). The survey consisted of two parts, structured interviews with the household, and complementary semi-structured interviews with key informants. The household survey uncovered the extent and quality of the events as experienced by those directly affected by outdoor environmental hazards, and semi-structured interviews revealed the opinions of those who are academic experts in these fields. The core of the survey was the household survey in the form of a questionnaire presented to a sample of 300 households in two geographical areas within Houston, the Ship Channel and the South-West study area.

Structural interviewing and large household survey are not used here as a mean for a positivist explanation of air pollution and ill-health but as evidence of the extent of the problem and an indication of non-directly operating causal processes. The questionnaire was historically informed hence the response were also expected to uncover relations of connection. This research has adopted a combination of extensive and intensive approaches because the thesis needed to provide the essential, but unavailable, extensive information on the state of child health in Houston (see section 3.5.1), and also to supply information about the quality of the problem in different areas in order to establish relations of connection to social structures and environmental features. Without denying the analytical value of intensive research strategy that concentrates on a small number of in-depth interviews, this technique was inadequate for approaching the enquiries of this thesis and the way that the methods are combined here indicates that it is not necessary that the number of cases should be small in order to establish substantial relations entered by identifiable agents.

The household survey is thus used in two ways. As an extensive research source it provides information on the total sample and the general trends of child ill-health and of air pollution. The rationale behind the use of a large-scale, formal structured interview as extensive research is that by asking each respondent the same questions, generalizations are possible. It serves the essential purpose of identifying the magnitude and characteristics of the problem of child ill-health and local air pollution but is clearly not intended to explain why the patterns occur. The extensive research described the household data but not actually connected with one another. In this way, for example, the percentage of households that reported child ill-health is measured in relation to the percentage of households which did not report ill children. At the beginning of Chapters 6 and 7, extensive quantitative analysis of the questionnaire produces evidence of aggregated formal relations.

However, the surveyed population was randomly selected, then households that shared similar causal powers and liabilities, that is, socio-economic status and geographical location in relation to industrial sources of air pollution, were grouped. This enabling extensive and intensive research designs to become more complementary (Sayer, 1992).

While some patterns were discernible at the level of overall survey, their empirical explanation remains largely a mystery. The move to intensive research was the classification of respondents by causal groups because intensive research focused mainly on groups of households whose members were 'either similar or different but which actually related to each other structurally or causally' (Sayer, 1992, p. 244). Identifiable households were looked at in their respective social and spatial contexts, which made simple relations apparent in terms of causal associations.

The comparative study consisted of examining the same variables in the surveyed households; these were classified in two related groups which responded to socio-economic status and their geographical location within Houston as to distance from sources of industrial pollution. By focusing on child health variation in geographical and social perspectives, the total data obtained from the household survey became more intelligible. It was like switching the light on (Sayer and Morgan, 1985).

In comparative study only contingent social relations are potentially significant as they combine with more general and structural conditions in forming actual historical outcomes in different places. Contrary to practice in the natural sciences, where a comparative 'experiment' usually involves real physical control or manipulation of a system of interest (see section 2.4), here the scientific 'experiment' refers to the control and manipulation of observations of a system which is not itself controlled. In the social sciences, these apply to a class of entities in which each member has an attribute which is observed to be at a different level, amount or strength (Sayer, 1992). The social world cannot be put into test tubes or laboratory cages (Dickens *et al.*, 1985). Comparative analysis seems to offer a way out, the possibility of finding real-world test tubes where history, economy, ecology and geography, i.e., the natural and the social worlds, set up the experiment. Comparison of cases avoids structuralist or empiricist determinism.

In summary, as an intensive research technique, the household survey prioritized information about processes. Comparison of responses entailed examination of actual connections and the search for relations of association. By focusing on households as causal groups, explanation of variation of reported child ill-health became apparent in terms of household spatial location, income, family structure, reported levels of air pollution, and so on. The two types of design, i.e., extensive and intensive, asked the same sorts of questions, used the same techniques and methods but defined their objects and boundaries differently. The techniques worked with different conceptions of groups. Extensive research concentrated on the overall sample of households, and intensive research focused on households by causal groups. The use of the two techniques proved the advantages of combining extensive and intensive research and quantitative, comparative and causal analyses. The use of intensive research is the strategy in establishing empirical causal connections between the parts of the whole as defined in critical realism (see section 2.8.3). Comparative strategy attempted to respond to the question, 'How did specific variations emerge in relation to general structures?' (Sayer, p. 244). In terms of particular, real, cases the attempt is made to distinguish how elements common to those cases have become unique to one case. In other words, how particular spatial distribution of reported child ill-health within Houston has originated in relation to outdoor industrial pollution.

The combination of comparative analysis and contextual examination had relevant implications for testing theory, for linking the theoretical and the empirical, for policy-making, and, not least, for reconceptualization of the relationship air pollution, child ill-heath and economic growth in Houston.

3.5 Research Operation

In this section the need for original data on Houston is discussed; the household survey in two study areas within the city and the questionnaire are explained; and the semi-structured interviews introduced. Appendix A discusses in detail the selection of areas and households for study.

3.5.1 *Collection of Child Health Data*

Data collection was preceded by acknowledgement of the lack of appropriate information in Houston and after conceptualization of their usefulness with regard to the objectives of the thesis. The investigation began in January 1990 with a search for information on environmental pollution and child health in Houston. This allowed an evaluation of both data availability and access to them. It was clear from the beginning of the exploratory research that data on child health was very limited and lacked geographic and socio-economic information.

A further difficulty encountered in the exploratory stage was that while city-wide public health data were available, they were very limited when it came to sub-areas within Houston. There were data on social, demographic, and public health characteristics of the population living within the boundaries of the so called 'Health Service Clinics Areas' (The City of Houston Health and Human Services Dept., 1984-1988; see Appendix A.1). In each one of these areas - 11 altogether - one city clinic serves the local population (clinic services are free but admission rules apply). These were useful in the initial stages to help visualize general living conditions in different parts of the city. However, the social parameters used in their health statistics focus only on demography.

The possibility of surveying patients in local clinics run by the city's authorities was dropped owing to three main obstacles. First, the administration of the city clinics was reluctant to act promptly to allow a survey and required complex procedures to obtain official permission. Second, interviewing parents who took their children to the city clinics would have omitted a large population who did not visit these clinics but still lived in the same residential area. While the clinics are open to everybody, it is mainly the poor who make use of them. Thus, the more affluent would not have been represented in such a sample. Third, the criteria for geographical location of the health areas held no significance for my study because neither social status nor distance from sources of industrial pollution were included. Another possibility explored was to obtain information on public child health from hospitals. However, information in hospitals was not completely computerized and access to it was almost impossible due to rules of confidentiality. In any case, only data from patients' discharge books would have been available. This information is usually very brief and would have provided only a narrow view of the problem (A. Mintz, personal communication, February 1992). For example, discharge reports from hospital would not have pointed out the household income or the usual symptoms children exhibit when pollution levels rise. The household survey carried out for this thesis provides that information.

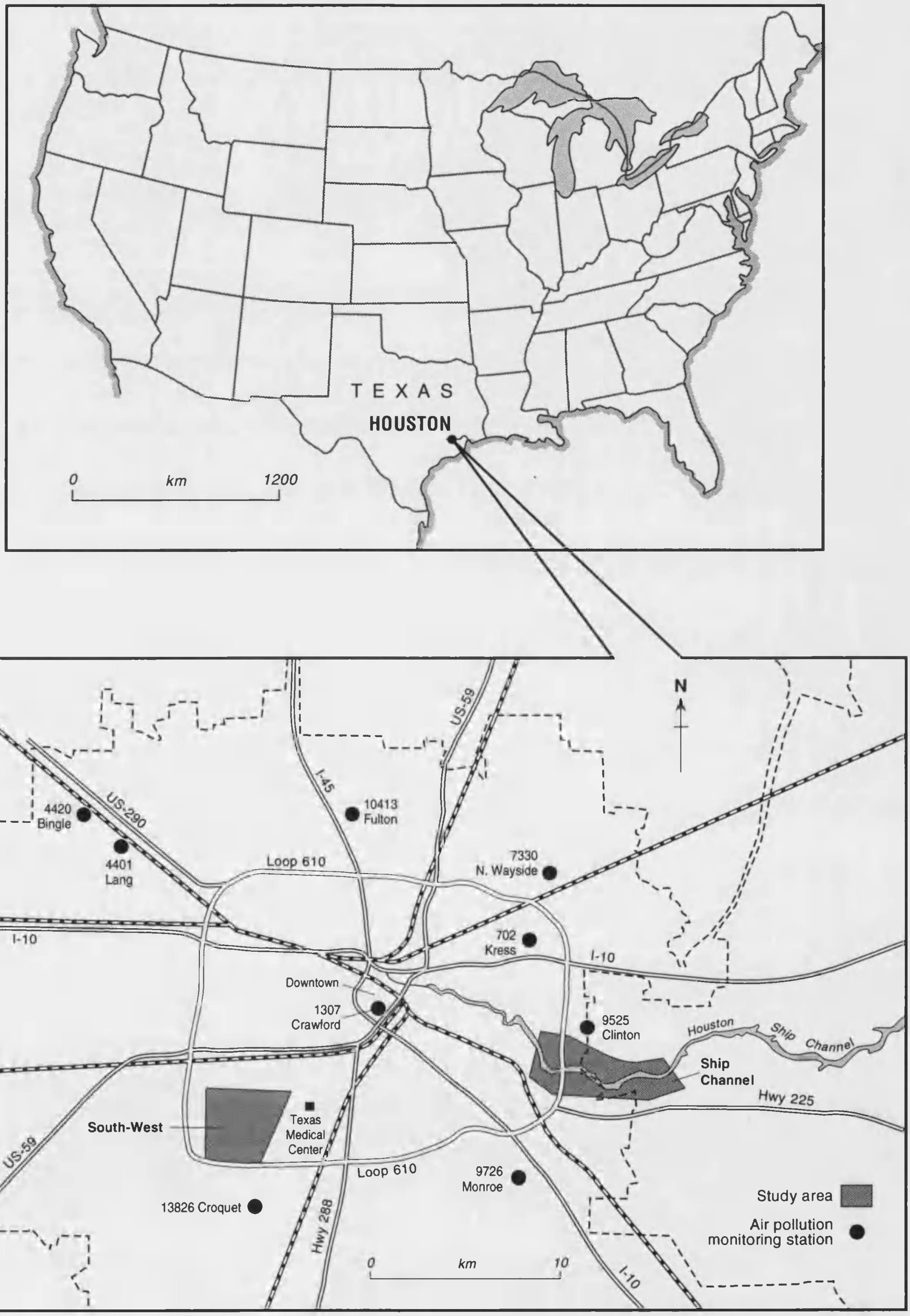
In summary, apart from the city-wide health information, virtually no useful information existed on the state of child health. This fact reflected not only many deficiencies in the administrative health system and information banks but also hinted at deeper contradictions. How could it be that data on child health were practically unavailable in a city housing one of the most important and the world largest medical centres? How was it possible that, despite the fact that industrial environmental pollution is a recognised problem in this highly developed and wealthy city, there was hardly any concern for the effects of air pollution on the health of the residents? For example, there were no official data available on the relationship between the incidence of asthma and levels of air pollution. Altogether, the difficulties encountered in obtaining official information were enlightening. They highlighted the need for procuring essential data, hinting at the usefulness of surveying the population, and promising an authentic contribution to knowledge.

3.5.2 *The Household Questionnaire*

The focus of data collection on the state of child health and local environmental conditions was the Houston household questionnaire. In this and following chapters, the term *household* has been used according to the definition of the General Household Survey, 1971. A *household* unit consists of members of one household who are a couple or one person without a partner and any of their children, provided these children have never themselves been married and have no children of their own (Office of Population Censuses and Surveys, Central Statistical Office, 1973).

The household questionnaire investigated (i) relative incidence and type of child-ill health; (ii) socio-economic characteristics of the household; (iii) health care; (iv) local air pollution. Because of the extent of variation expected between households it was essential to take a relatively large sample. Representative households within the city were thus selected by way of cluster sample which involved the random selection of two geographical units combined with the assessment of every case within the geographical units (Healey, 1990). Three criteria were employed to select the study areas: spatial location in relation to industries and refineries in the Houston Ship Channel; socio-economic status of residential area; and levels of local air pollutants (see Figure 3.2; see Appendix A.1 for more details of the method used for selecting the geographical study areas and for sampling houses). Location was important as it was assumed that proximity to polluting sources was a main cause for exposure to higher levels of local air contamination and hence, ill-health. Socio-economic status was a significant criterion because it was anticipated that poverty would be a most influential factor in child ill-health. The degree of exposure to environmental pollution was treated both as the result of contingent circumstances of the household but not least importantly as a necessary consequence of the inherent

Figure 3.2 The city of Houston and the study areas



characteristics of pollutants and proximity to source of pollution. The selected areas were thus polluted and less polluted, with poor and wealthy sub-areas within them.

The questionnaire produced a large amount of data on 300 households in Houston. However, it also rendered useful and relevant information to determine causal relationships because the socio-economic conditions and location of the household were properly identified. The questionnaire was thus used to collect standardized information from a randomly selected population, i.e., in low and high-income households located near to and far from (used primarily as the control population) the petrochemical and industrial area and with high and lower levels of air pollution which enabled the author to carry out cross-sectional analysis for comparative study (Vaus, 1986; Healey, 1990).

The household questionnaire, the *Air Pollution and Child Health Survey* - the APCHS, Houston, 1990 - was conducted between June and September 1990 in the Ship Channel and the South-West areas. The questionnaire followed the guide-lines of Vaus (1986) and Robson (1993) from the construction of the questions, through a pilot study to the formulation of the final questionnaire (see Appendix B). A closed format was used for the question design, with a number of alternative answers for most questions. Although the questionnaire was based on structured interviewing, by administering it personally I was able to gather additional comments by the respondents. Only households with at least one child were surveyed and only one questionnaire was filled in for each household. Interviewing was carried out by the author. The questionnaire was addressed to the mother because of her active economic and social role in the household, for the large number of single mother households in Houston (and in the sample), and because mothers are usually more involved with the health of children (see section 6.4). In a few instances, when the mother was not at home, fathers answered the questionnaire.

The questionnaire took between 25 to 30 minutes to complete, including any additional comments that the interviewee wished to make. In general, the questions were read out to the respondents and I wrote down their replies. Sometimes, interviewees preferred to fill the questionnaires in on their own in which case I returned after half an hour to pick them up. The questionnaire was administered either in English or in Spanish (it was anticipated and found that many respondents, particularly in the low-income areas, would be Hispanic). The wording of the questionnaire responded to local usage (for example, sub-division for district; dissertation for thesis). The response rate was 100% although sometimes certain questions in the questionnaire were not answered (e.g., household income).

3.5.3 *Semi-Structured Interviews*

Individual semi-structured interviews with various key informants were aimed at exploring their ideas on the state of health of the population and environmental conditions in Houston. The purpose was to register the perspectives of professionals who were directly involved in the health care of the community and the control of air pollution in the city for two main reasons. First, as some issues were difficult to evaluate through direct questions in the household survey, semi-structured interviews with public sector general practitioners, hospital doctors, academics and air pollution control staff sought to provide complementary and particular knowledge regarding each area of the research (see Appendix A.3). Second, although the number of these interviews was small, they were aimed to complement and strengthen the power of arguments and interpretation of quantitative and comparative analyses derived from the survey questionnaire.

The information given by the interviewees provided further contextual backdrop important for interpretation but it was not the purpose of the research design to carry out qualitative analysis by interpreting the meaning of this information. I had a few questions designed for each interviewee but I used questions and responses to generate more questions and further information. One subject lead to another in such a way that I could cover the subject of investigation.

3.6 Analysis of Extensive and Intensive Information

In interpreting the fieldwork, the realist conceptual distinction between identifying empirical regularities and explaining them is used in this thesis (see section 3.2.2). Quantitative and comparative, causal and qualitative analyses, the latter in the sense of political and economic theory, are the core analytical procedures of the thesis. Quantitative analysis was conducted on the survey primary data but also on secondary information. Descriptive and inferential statistics were produced. The data from the household questionnaire rendered not only the essential tool for identifying the extent of the problem of child ill-health but also provided the means to access relations of association - due to its intensive design and comparative approach - and thereby gave clues to causal relations. Inferential statistical analysis was carried out using associations and regressions, for example, of the prevalence of respiratory disease among children in the studied households, the location of the household and the income.

In the household study, data were first analyzed for descriptive purposes through statistical methods with the SPSS package (Roberts, 1991; SPSS Inc, 1989; Norusis, 1988). This analysis was used to measure and describe the magnitude and type of child ill-health and levels of air pollution in the studied areas. A great deal of preparatory work was needed before the variables could be compared and the choice of a control sample was essential. The comparative analysis in this thesis was a very focused 'experiment' associated with a scientific approach and based on a factorial design (factorial because it involved more than one independent variable). The study corresponded to a 'two by two' design and four causal groups were compared (Robson, 1993). There were two independent variables, household location and socio-economic circumstances, each of which had at least two levels: polluted and less polluted, and low and high income.[8] The comparison employed one study area and one control area. The data originated in the thesis' household survey, the APCHS. The study design was also parametric because it incorporated a range of levels or values for many other independent variables in the experiment so that a fuller picture of their effect could be obtained (Healey, 1990). The independent variables were carefully selected on the basis of both previous literature and the purpose of the thesis. These variables were manipulated and their effects on the single dependent variable, child health, were treated as the outcomes. It was also possible to extrapolate the effects from the comparative sample and apply them to the population from which they were drawn. Inferential statistics generalized the findings from the sample to the population in the randomly selected study areas. Multiple cross-tabulations and correlations were used and the test of statistical inference was chi-square (see Appendix A.4 for more details on the statistical analysis).

However, neither quantitative descriptions nor the outcome of comparative analysis and quantified relations were considered as ends in themselves but rather as essential clues to the existence of particular processes that could explain the events.[9] Although preliminary stages involved quantitative analysis, and comparative analysis indicated that there was a range of processes not directly observable, causal analysis followed. Associations found in the comparative

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[8] The term socio-economy is here employed to describe conditions in the household, i.e, micro-structures, whilst the sociological approach discussed in section 2.5 focuses on this dimension; the term social is used in the sense of societal structures and historical processes, i.e., economic, political and spatial.

[9] Quantitative analysis is weaker for the purpose of explanation. The relations it discovers are formal, supposedly objective, concerning similarity, dissimilarity, correlation and the like, rather than causal, structural and substantial, that is, relations of connection (Sayer, 1992) (see section 2.4.2, on the limitations of the biomedical explanation).

analysis were indicative of contingent relations causing differences, processes taking place and therefore calling for further scrutiny. The contextual knowledge on regulatory institutions, levels of air pollution, economic and environmental changes over time, and essential information on physical mechanisms were combined to conduct causal analysis. The aim of causal analysis is to discover the role of structural and spatialized underlying factors in causing air pollution and the incidence of child ill-health in Houston. Anecdotal or insight comments by respondents during the structured interviews were treated qualitatively and used to strengthen the overall argument. Integration of the theoretical views completed the qualitative analysis. For example, linkages could be established between current levels of industrial contamination in the city and historical processes of economic growth.

The general explanatory approach consists of contextualizing current empirical findings of the household and their variations by situating them in Houston's historical development, environmental regulations and health provision, and of connecting those to historical social processes. Hence, the relevance of highlighting the structural character of the spatial form. It was enriched by the semi-structured interviews, and finally, the explanation integrates the resulting causal analysis with the political and economic theoretical perspective of economic growth and environmental degradation.

3.7 Conclusion

Chapter 3 has defined the issues of study and highlighted their relevance for the purposes of the research and the historical currency of the themes, and has justified the methodological design, outlined the operation of the field work, and explained the analytical approaches used in the thesis. The investigation in this thesis uses a mixture of extensive and intensive research methods to address and compare the facts and to examine structural factors. The household survey is the core of the field-research.

The point was made that the fundamental task of quantitative analysis in the thesis is to investigate the trends and dimensions of the events. The combination of aggregated, comparative, causal and qualitative analyses reveals relations of association and of causality. The four analytical approaches complement each other in describing and explaining the phenomena under investigation. This is a combination which is strongly shaped by the methodological premises of critical realism but which has not been normally employed in political and economic environmental research. Causal analysis is used to explain the findings by connecting the analysis of the field work to physical mechanisms of causation and to identifiable social structures. The chapter has elaborated a causal method of analysis to address the historical conjuncture and the empirical relationships between air pollution and child ill-health. The analytical model which the thesis will employ integrates events, mechanisms and structures, interprets spatial forms, and consolidates them through a political-economy perspective. The conceptual framework that is used, as discussed in Chapter 2, captures significant principles of the configuration environment, health and society, assimilates both the utility and the criticism of basic scientific theories and methods, interprets social and other contingent events, and provides explanations to historical and spatial patterns of air pollution and of child ill-health as found in the household survey. The causal model is the result of theoretical and methodological postulates.

The overall operation of the research is presented in the thesis through a set of five themes. These are historical trends of growth in Houston, rise of environmental pollution, and the current state of air pollution in Houston; spatial variation of risk and resident's views of Houston's environmental crisis (Chapter 4); the institutional aspects of pollution control and of health care, and the public health rates (Chapter 5); social and spatial variation of child ill-health in the study households (Chapter 6); and integration of spatial structural patterns of air pollution, industry and child ill-health in the study areas and the presentation of causal explanation (Chapter 7).

CHAPTER FOUR

ECONOMIC GROWTH AND THE CORRESPONDING RISE OF AIR POLLUTION AND HEALTH RISK IN HOUSTON

4.1 Introduction

Chapter 4 attempts to construct a solid analytical framework of the economic and urban development that took place in Houston since the beginning of the century and to situate its environmental crisis within this context. The aim is to link historical trends of economic growth to industrialization and concomitant environmental degradation, to current spatial patterns of risk, and to national and international strategies of capital accumulation and government support. The chapter argues that, significantly, the same process that brought remarkable growth to the region caused notorious regional pollution. It also reasons that economic growth and environmental changes are intricately linked. Conceptually, two processes take place, the interconnection of social and physical systems, and the independent action of natural mechanisms (see Chapter 2). Finally, it is claimed that the contradictions of capitalist economic growth are better understood if the effects of spatial convergence of industrial facilities and increased levels of air pollution are considered. The chapter reveals a coincidence of events evident in spatial forms of increased risks, hazardous environments and industrial concentration.

Chapter 4 combines physical and social aspects of economic activity and environmental pollution in Houston. In the social sciences, nature has made an appearance as something which is being affected by the economy (see section 2.7). But what the 'something' is, how and why it is being ruined, and how it relates to human beings, has hitherto remained inadequately discussed. Chapter 4 addresses these questions in analytical terms by examining three themes. First, economic changes, particularly in oil industrialization, since the beginning of the twentieth century are articulated with subsequent degradation of the Houston natural environment providing a critical interpretation of outstanding economic growth and remarkable population changes. Second, the current contrasting characteristics of the city are outlined and interpretations of growth in Houston are reviewed. Third, the state of the environment in Houston is assessed based on early and current reports and studies by government agencies. Finally, spatial coincidence of structural activity and of increased risk is approached in terms of both historical residential and industrial settlement and residents' exposure to chemical accidents and associated risks.

4.2 Historical Economic Context of Environmental Degradation in Houston

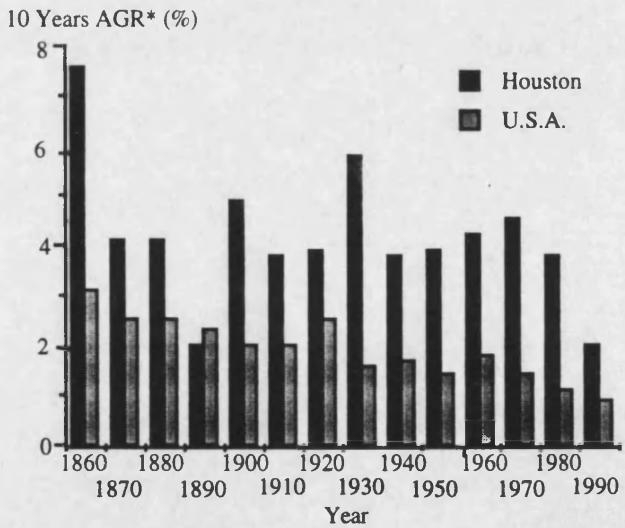
The purpose of this section is to analyze the forces that brought economic growth to the Houston region and the rise of local environmental pollution. It will construct the linkages between past and present environmental degradation and economic development in the region. In the assessment below, Houston population and economic growth, and environmental changes are traced by focusing briefly on the period from the beginning of the century, and in more detail after the Second World War. Because of 'the lack of reliable, systematic sources of information on the extent of pollution in the early period' (Pratt, 1980, p. 249), the present researcher needs to rely on two main historical sources, J. Pratt 's work (1980) and that of Williamson *et al.* (1965, 1963).

4.2.1 *Houston Area and Population*

The city of Houston which extends over 1,776.81 square miles, is located on the upper Gulf Coast prairies of the Gulf of Mexico in the state of Texas (see Figure 4.1). The location of Houston is one of practical isolation in relation to other main US cities. Houston and the surroundings counties - Montgomery, Fort Bend, Liberty and Waller- comprise one extended metropolitan region, the Houston Metropolitan Statistical Area (MSA, 5,435.48 square miles). The Houston Metropolitan Consolidated Area (CMSA, 7,422.38 square miles) consists of three PMSAs (Primary Metropolitan Statistical Area), Houston, Galveston-Texas City, and Brazoria.

In 1990, Houston was the fourth most populous city in the USA (2,8 m.) and the largest in the South and the South-West. The Houston-Galveston-Brazoria Consolidated Metropolitan Statistical Area's (CMSA) population (3,7m.) ranked tenth among the country's metropolitan areas, and was the largest in the South and South-West of the USA. Historically, population growth rates in the MSA between 1860 and 1990 have been above the USA's (Greater Houston Partnership, 1992) (see Figure 4.1).

Figure 4.1 Population growth rates, Houston and USA, 1860-1990

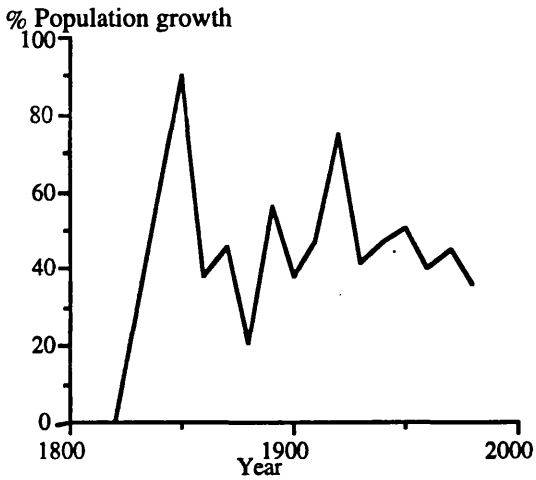


Source: U.S Bureau of the Census, in Greater Houston Partnership (1992).
* Average growth rates

By 1860, Houston was the most important rail centre in the state and the dominant city in the region (Thomas and Murray, 1991). While Houston experienced a near linear population growth pattern for most of the twentieth century (see Figure 4.2), population growth per decade in the period between 1850 and 1980 was striking

- an average increase of nearly 50% for the metropolitan area. Between 1930 and 1980, annual population growth was remarkably constant, about 3% a year. Feagin (1988) claims that these rates of population growth, over so many decades, are probably the most sustained for any city in the USA.

Figure 4.2 Houston population growth, 1850-1990



Source: Data from US Bureau of the Census; Houston Chamber of Commerce, 'Houston Data Sketch', 1981, in Feagin (1988, pp. 7-8).

Houston's growth rate dropped in the 1980s, but even the reduced population gains were about twice the national average. Houston still ranked high in growth percentage when compared to the other large metropolitan areas in the USA (see Table 4.1). Specifically, the Houston MSA's 17.0% gain placed it third among the 10 largest urban areas, just behind Los Angeles, which had a 17.2% gain (Thomas and Murray, 1991).

Table 4.1 Ten largest MSAs ranked by percentage population change, 1980-1987

Rank	*MSA*	*Percent change*
1	Dallas-Ft. Worth	27.1
2	Los Angeles-Anaheim-Riverside	17.2
3	Houston-Galveston	17.0
4	Washington, D.C., Maryland	12.2
5	San Francisco-Oakland-San Jose	10.9
6	Philadelphia-Wilmington	3.7
7	Boston-Lawrence-Salem	3.0
8	New York-Northern NJ-Long Island	2.9
9	Chicago-Gary-Lake Country	2.6
10	Detroit-Ann Arbor	-2.6

Source: Patterns of Metropolitan Area and County Population Growth: 1980-1987, U.S. Bureau of the Census, in Thomas and Murray (1991).

Thomas and Murray identified that what accounted for Houston's place at the forefront of the surviving urban growth frontier were employment increases in the metropolitan area. The number of manufacturing and non-manufacturing jobs was significantly augmented between 1950 and 1982. Manufacturing jobs increased about five times, while non-manufacturing grew at an even faster rate (Feagin, 1988) (see Table 4.2). Based on a comparison of labour force data from 1970 and 1980 U.S. Censuses, Thomas and Murray (1991) confirmed a direct relationship between new jobs and employment growth and, hence, population growth. Moreover, Houston was second in the USA in both employment gains (80.7) and in rate of population gain.[1]

Table 4.2 Employment in Houston, 1950-1982

Year	*Manufacturing (units)*	*%*	*Non-manufacturing (units)*	*%*	*Total (units)*	*%*
1950	59,200	25	180,000	75	239,200	100
1960	96,400	25	284,600	75	381,000	100
1970	145,600	23	500,700	77	646,300	100
1980	218,900	19	953,600	81	1,172,000	100
1982	254,000	16	1,329,400	84	1,583,400	100

Source: U.S. Bureau of the Census, in Feagin, 1988, p.77.

4.2.2 *Economic Development and Rising Pollution*

> *It is likely that at least as much oil found its way into the region's ground, water, and air in this period as found its way to market (ibid., p. 228).*

Economic growth has taken place in Houston since the beginning of the century. Today, about one quarter of the USA's oil refining capacity, one quarter of the oil-gas transmission companies, and one half of all manufactured petrochemicals made in the USA, are located in the Houston-Gulf Coast area. The general trade passing through the Port of Houston reflects extensive commercial activity in the area (see Plate 4.1). In the 1990s, the port ranks first in the USA in terms of foreign tonnage and second in

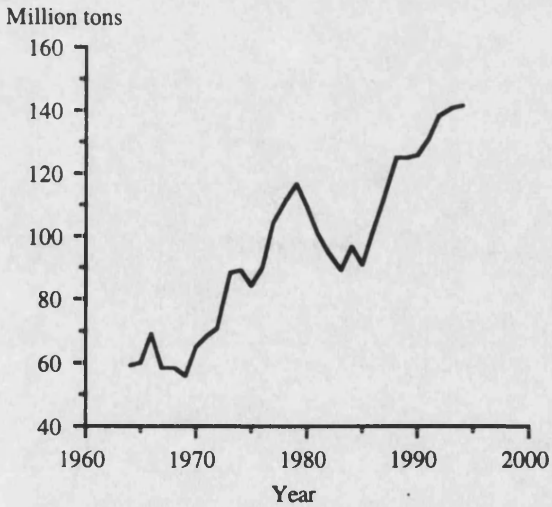
[1]During the 1980s, Phoenix had the largest proportionate increase in employment and the largest percentage gain in population (Thomas and Murray, 1991).

total tonnage (Port of Houston Authority, 1995). Figure 4.3 illustrates the rising trend since the 1960s.

Major environmental problems have existed in the Houston area as a result of failure to deal adequately (if at all) with industrial waste from petrochemical and primary metals production. This, combined with municipal waste produced by a growing population (see section 4.2.1), and car emissions that accompanied the

Plate 4.1 A view of the Ship Channel and the port of Houston displays the dominant presence of petrochemicals along the channel.

Figure 4.3 Cargo tonnage in the Port of Houston, 1964-1994



Source: Data from Port of Houston, U.S. Corps of Engineers, MR 14/3/95 expanding use of the automobile, made Houston one of the most seriously polluted areas in the USA. Earlier, coal-burning trains had brought unhealthy smoke to Houston; the rapid clearing of timber had stripped the soil of its protective covering; and the milling of this lumber in coastal towns like Beaumont had resulted in contamination of Houston's air. The discovery in the early twentieth century of oil in Houston and its surroundings brought significant new types of pollution, greatly increasing the region's environmental problems. Clearly, 'in the rush for instant wealth, oil was seen as black gold, not black sludge' (Pratt, 1980, p. 227).[2]

Speed and quantity of production - rather than efficiency and the prevention of waste - characterized the early period. Although the exact levels of air and water pollution in the Houston area could only be roughly estimated, it is clear that environmental pollution was a problem at a very early date. Several days after the discovery of the first well in 1901, the Spindletop, massive pollution followed: a thick, yellow, sulphur-laden fog began periodically to discolour houses and threaten the lives of some of the drillers (Pratt, 1980). Oil extraction often led to massive drain-offs of crude oil that soaked the ground; the rapid removal of oil from the wells also resulted in the introduction of salt water into the underground reservoirs of oil and into the region's water system. For lack of better storage facilities, producers often used unsafe open earthen pits and wooden tanks. Adequate transportation and loading facilities did not exist, so large quantities of oil were lost between pumping stations and the tankers that carried much of the crude to the East Coast.

Oil production on the Gulf Coast, and in Houston in particular, increased dramatically between 1929 and 1941. Most prominent was the great East Texas field, discovered in 1931, which in less than 10 years multiplied about eight times the number of producing wells in the Houston area, from 3,612 in 1932, to 25,765 in

[2]Pollution problems from oil refining fall into two main categories. First, pollution arising from the production process - drilling, transport, refining (including accidents and explosions)- and the petrochemical industry refineries emitting toxic hydrocarbon vapours, combustion waste gases, sulphur-containing gases, and fine particles. Second, problems arise from the consumption of oil, e.g., car emissions, and the so-called 'green-house effect' or global warming, and from accidents (Strauss and Mainwaring, 1984).

1939 (Williamson *et al.*, 1963). It is still among the most productive in the USA (Thomas and Murray, 1991). Oil production in the Gulf Coast area continued to increase four fold between 1929-1941, from 57 to 226 millions barrels (Williamson *et al.*, 1963).

Houston enjoyed a long boom period in the aftermath of the Second World War based on the rising demand for oil products; construction companies, truck, pipeline, and shipping companies grew around Houston oil; most of the USA's largest oil companies located administrative, research and production facilities in this metropolitan area; and there has been collaboration since the 1950s between Houston oil companies and oil fields from Malaysia and Saudi Arabia to the North Sea. Most large oil fields opened within the global economy brought new growth to Houston.

The city expanded horizontally and vertically, with its seven business centres and hundreds of major plants, office towers and shopping centres, Houston had more than 1,200 oil companies and supply houses; 'oil facilities, from refineries to office skyscrapers were the concrete embodiments of a continuing oil boom '(Feagin, 1985, p. 1214). The growth trends which have prevailed in Houston in relation to the other five largest US urban areas are illustrated by the continuous rise in capital invested in manufacturing, especially in refineries and petrochemical plants between 1967 and 1982 (see Figure 4.4).

Such intensive economic activity resulted in severe environmental degradation already early in the century. The growing refining complex on the Gulf Coast caused considerable pollution, but for most of the century no institutions - either public or private death had sufficient power or incentive to deal effectively with the resulting problems (Pratt, 1980, p. 225). Before the government started regularly to monitor air pollution in the 1970s, the first environmental survey in the region in 1923, the *Pollution by Oil of the Coast Waters of the United States* [3] reported that the Houston Ship Channel, which is the location of the petrochemical installations and the port,

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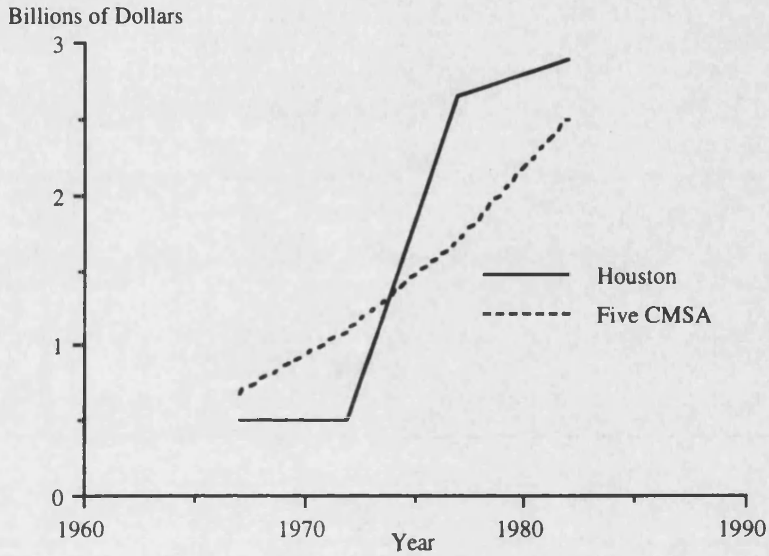
[3]This was a comprehensive investigation of national water conditions. The American Steamship Owners' Association and the U.S. Bureau of Mines cooperated in completing the survey (Pratt, 1980).

represented 'one of the worst oil polluted localities seen by the Committee' (Pratt, 1980, p. 234). The economic activities which gave rise to such environmental destruction have, nonetheless, continued to operate, and concomitantly, further environmental degradation followed.

Figure 4.4 New capital investment in manufacturing: Houston and the mean for the five largest CMSAs,* 1967-1982



Source: US Census of Manufacturing, adapted from Thomas and Murray, (1991, p. 50.)
*The five CMSAs are New York, Chicago, Los Angeles, Detroit, and Philadelphia.

In summary, more than 20 years later, in the 1956-1958 survey of the Houston area, it was officially disclosed that the 'air pollution problem resembled that of Los Angeles'which had captured the nation's attention since the late 1940s (Air Pollution Survey of the Houston Area, 1956-1958, cited in Pratt, 1980, p. 243). Industry was cited as the biggest polluter in Houston, with municipal sewage a major secondary source. The follow up survey in 1964-1966 revealed how quickly the limits to natural pollution dispersal could be reached in Houston in a period of rapid growth. The conclusion to be drawn is that the findigs of these latest environmental reports were no less distressing than those of the first national pollution survey of 1923, which had acknowledged for the first time the severity of contamination caused by economic growth. Furthermore, in 1990, the results of the first Texas Environmental

Survey (see section 5.2), which collected people's opinion on regional environmental problems, highlighted the pervasive presence of air pollution in the Houston area.

4.2.3 *A City of Contrasts*

Commitment to business has barely been associated with anything other than success, and the city's splendour and growth have attracted open admiration (see section 3.2.1). Houston has gained a reputation for outstanding economic success while the fact that the quality of life in the city is poor has been ignored. The severity of air and water pollution, and the social consequences resulting from this type of 'successful' economic growth have, in fact, been hidden behind material achievements. Yet environmental degradation has been severe and economic prosperity unequally distributed. Indeed, while two of the five wealthiest suburban areas in the USA are situated in Houston, huge areas of poverty, large minority ghettos and severe environmental pollution (and remarkable ill-health as illustrated by the thesis), also characterize the city.

Awe, admiration and disgust for the city cannot be avoided because Houston's current built environment is impressive, unique and grotesque at the same time. Amidst a flat and dull landscape stands a seemingly impenetrable conglomeration of high-rise buildings. This is the central business district, or downtown (see Plate 4.2). The flat surroundings seem intimidated by the presence of this cohesive mass of skyscrapers, many of which exceed sixty floors in height. A few other isolated groups of very high buildings can be distinguished on the city's horizon (see Plate 4.3). Here and there 'a shopping centre disrupts the pattern by its scale' (Jackle, 1994, p. 307). The dominant character of these high rises is accentuated by the fact that many of them are built wholly of blue, turquoise or brown glittering glass. The Houston Medical Center presents distinctive characteristics of affluence (see Plates 4.4 and 4.5).

Plate 4.2 Typical Houston landscape, seen from the 610 Loop (see Figures 3.2 and 4.5) showing Downtown's prominent sky-line which contrasts the flat surroundings. After a pronounced turn on the I-59 high-way, the conglomeration of buildings in Downtown makes its sudden appearance like a cohesive, imobile monstrosity made of different shapes, heights, materials and colours.

Plate 4.3 The Transco Tower, situated in a popular commercial sector of the city (the Galleria) is the site of oil-related offices and the tallest building in Houston. Looking like a chocolate bar, as it is popularly known, it is simply an eye-sore to the landscape. Impressive height and ostentatious presence of the Transco Tower epitomizes the embodiment of capitalist growth, flourishing business and powerful multinationals in the city.

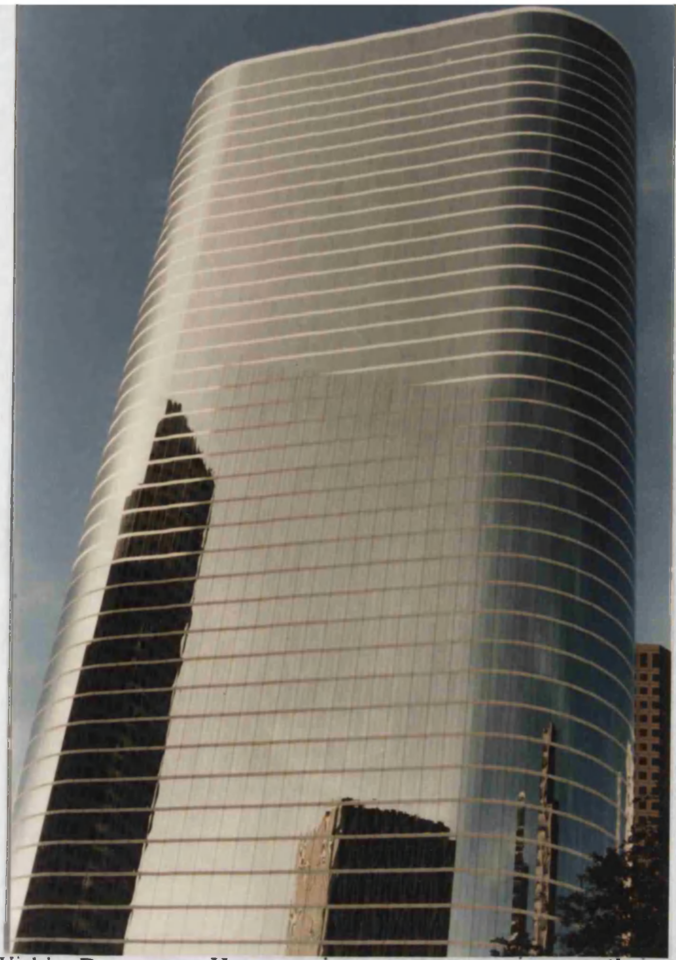


Plate 4.4 Within Downtown Houston, immense economic growth is reflected on sumptuous construction. Office development took place in the centre of the city with new and old buildings staying side by side.

Plate 4.5 'Houston Medical Center', located in the south-west of the city, with its outstanding reputation attracts patients, doctors and researchers from all over the globe. Howerver, provision of health care in Houston, as anywhere else in the USA, is mostly privately paid. Facilities in some hospitals, e.g., Episcopal Hospital, resemble those of a five star hotel.

The presence of numerous highways is another prominent feature. Very wealthy neighbourhoods of mansions and tree-lined boulevards are found in Houston and such social and spatial exclusivity is characteristic of many American cities (Wyckoff, 1994).

But not all that glitters is gold. The horizon of the city seems to expand forever with no interesting vestiges of nature to attract the observer's attention. Along main roads and highways, one can see derelict and rusting cars, abandoned buildings, empty land, and poor houses. Conditions in some low-income neighbourhoods are rundown, with decaying flats, both old and newly built, minority quarters, and common such eye-sores are in the vicinity of well-off residential area . Weather conditions in Houston are quite extreme. High temperatures and unbearable humidity reign for more than six months of the year. Average temperatures range between 56ºF and 76ºF, and with a relative humidity of 76% (Macdonald, 1976). To facilitate life in this climate, most buildings are air-conditioned. Houston's population cocoons itself from the heat within artificially air conditioned buildings. Within Houston's extended city, mobility is predominantly by private car, congestion is commonplace and public transport is very deficient.

Unpleasant smells from oil and gas refineries usually invade the city (see Plate 4.6). There are major problems in routine sewage and garbage disposal. Unique problems of subsidence affect the city. Many areas are actually sinking as a result of vigorous development, and flooding problems have increased through subsidence (Feagin, 1988). Water supply is inadequate and there is persistent water and air pollution. In Houston, outdoor air conditions are usually very unpleasant. In addition to high temperatures and humidity, emissions from numerous cars and industry, and the heat produced by central cooling equipment contribute to at times unbearable air quality.

This chapter serves to reinforce the thesis' claim that Houston has become a capitalist heaven, but, not least, an environmental hell. The natural environment in the area has been adversely affected by nearly a century of uncontrolled economic activity and political pro-growth support. The next section moves on to analyze the social processes that contributed to make Houston a city of contrasts with a recognized environmental problem.

Plate 4.6 What could be a 'pure' pastoral scene in the San Jacinto Monument Park is abruptly disrupted by the presence of a solid background body of chemical establishments. Oil and gas processing plants are located within easy reach from main roads and the landscape these create has become typical of the east side of the city.

4.3 Capitalist Paradise / Pollution Hell

The forces that underlie environmental degradation, and air pollution in particular, are usually complex. The foundation of this thought was that there are visible and less visible mechanisms and structures which can be explained but hardly seen. Economic, political and biological factors are frequently found acting together and, often, mutually reinforcing each other. The purpose of this thesis is not, therefore, to give an absolute and final explanation of the process of environmental degradation but to highlight crucial political and economic processes which have usually been unaccounted for. The present section analyzes various explanations of economic growth in the Houston area. It stresses the position of the city within the international division of labour, and highlights the relevance of the process of global capital accumulation to local environmental pollution.

4.3.1 *Interpretations of Houston Economic Growth*

> *Houston's emergence in recent years as the unofficial 'energy capital' of the nation is the logical culmination of over three-quarters of a century of oil-led development (Pratt, 1980, p. 5).*

Two mainstream theories have frequently been employed to explain urban growth in Houston, those of development called *convergence* theories, and those of critical power-conflict termed *uneven development.* Convergence theories have emphasized that Sunbelt cities such as Houston are 'catching up' economically with northern cities, e.g., New York, which developed earlier, and that this convergence is part of a tendency towards equilibrium in US society. Sunbelt cities like Houston are seen as late-comers, their rise the result of decentralization from the hinterland, and substantial in terms of technological changes in transport and communication, with prosperity accomplished in the absence of state intervention (Hawley, 1981; Kasarda, 1980; Rostow, 1977; Williamson, 1965).

The uneven development perspective, on the other hand, has stressed uneven development as a normal aspect of cities embedded in the capitalist system (e.g., Smith, 1984). Perry and Watkins (1977) argue that Sunbelt cities have prospered by attracting leading industries, including electronics, defence, and oil. Northern, as opposed to Southern cities, have failed to capture these industries because of the commitment of investors to established industries in the North. The theory claims that development in one city is achieved at the expense of cities in other regions and that government plays a role in how intervention makes an impact (Hill, 1977; Perry and Watkins, 1977).

The two theories, however, are insufficient to explain growth, and concomitant environmental degradation, in Houston. The long-distance inter-city relationship was not one of filtering growth down an urban hierarchy but rather of moving corporate investment - often drawn from outside both cities - linked by a manufacturing need for processed raw materials (Feagin, 1985). The discovery of the Spindletop oil field 90 miles east of Houston, and subsequent discoveries closer to the city from 1905 to 1919, set the stage for the city to become a major oil and gas production centre (Feagin, 1988). Before this period, in the second half of the nineteenth century, Houston was already a well-developed commercial city, with full railroad and banking infrastructure, all aspects definitively contributing to the rise of the oil industry in the region (ibid.).[4] Later on, events in Detroit - the industrial city more than a thousand miles away where, in the 1910s, the mass production of the automobile was perfected - spurred investment by major oil companies and helped transform Houston into an oil capital. Moreover, the government played a key role in promoting development in Houston. Hence the next two sections explain why Houston is a capitalist paradise and why Houston became a pollution hell.

4.3.2 *The Promotion of Development*

The beneficial configuration of oil and gas, sulphur and water, and labour pools in the Houston area certainly contributed to the development of the petrochemical industry in the South (Thomas and Murray, 1991; Child Hill and Feagin, 1987; Feagin, 1988).[5] However, natural advantages alone could not spur growth in the region. In fact, the

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[4]By 1900, the city was an important agricultural commerce centre. Other economic activities were the extraction of sulphur, salt, lime and other minerals, and the cutting and trading of timber (Pratt, 1980). By 1920, Houston was the largest cotton market in the world (Feagin, 1988). Up until the late 1940s, cotton was the main export in the Port of Houston after which oil replaced it. By the late 1940s, cotton accounted for only 10% of exports through the Port of Houston, while oil accounted for 80%. Oil and gas industry had surpassed agriculture as Houston's dominant economic sector (ibid.).

[5]Given the volume and weight of petroleum, Child Hill and Feagin (1987) argue that there were obvious advantages to refining it near production sites. The refining process requires large quantities of fresh water and access to port facilities (or, later, to pipelines) that can move the finished product to market.

physical advantages in the Houston region could have been exploited with a different purpose and also in a different manner - or not exploited at all. Beyond the recognition that the presence of the natural quartet of oil and gas, sulphur and water in one place was essential in the development of the industry, the economic and political forces have been crucial to the way the region grew.

The city developed ties outside the USA economy when the major oil companies began to develop international operations in the 1920s and 1930s. The Gulf Coast oil industry moved quickly through the stage of competitive-industrial local capitalism to that of oligopoly capitalism dominated by major companies (Thomas and Murray, 1991; Feagin, 1985). By the late 1920s, 70% of Texas production was in the hands of 20 companies, although there were 14,000 oil companies throughout the USA (Williamson *et al.*, 1963).

Moreover, in the post-war period, the growth of Houston was facilitated dramatically by the federal government which had become a primary source of capital for, particularly, oil-related development previously linked to the war (Shelton *et al.*, 1989; Feagin, 1988).[6] Indeed, the spatial form and environmental characteristics of the city of Houston are not some easy and inevitable translation of deep-lying economic structural forces. Feagin argues, rightly, that specific economic and state forms do not develop inevitably out of structural necessity (1988, p. 24). They develop in a contingent manner as the result of the conscious actions taken by members of various classes, acting singly or in concert, under particular historical and structural circumstances. Spatial forms are contingent on the dialectical articulation between action and structures and 'structural changes are processed through human actions taken under historical conditions' (Gottdiener, 1985, p. 199).

The federal government and the local 'growth coalition' played a crucial and continuous facilitating role in the rise of the Gulf Coast city after 1902 (Thomas and

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[6] For example, in the 1940s, the national government embarked on a crash programme to develop a huge synthetic rubber industry, 'not surprisingly, the Houston Ship Channel was selected as the primary location for this new petrochemical industry' (Thomas and Murray, 1991, p. 46).

Murray, 1991; Feagin, 1988). Essential infrastructure for the development of the oil industry, such as port facilities, the Ship Channel, and city roads were improved with federal funds. Governmental subsidies were secured by local bankers, real estate investors, top governmental officials, and other leaders - the so called 'growth coalition'[7] - who lobbied for government monies.[8] In this sense, the active role of the 'growth coalition' was very important. Crude oil operations increased consistently in the 35 years of operation between 1941 and 1976. The total refining capacity of the Houston area rose more than in any of the four competing areas in the Gulf Coast (Houston, Beamont-Port Arthur, Corpus Christi, and Louisiana Gulf) (see Table 4.3).

Table 4.3 Operating crude oil capacity of Houston on the Gulf Coast, 1941-1976

Year	*Houston* production*	*Houston % of Gulf production*	*Beaumont-Port Arthur % of Gulf production*	*Corpus Christi % of Gulf production*	*Lousiana Gulf % of Gulf production*
1941	472,800	40.5	38.6	9.1	11.8
1947	539,300	34.4	37.1	6.0	22.5
1951	740,200	36.2	35.2	4.6	24.0
1956	925,600	34.3	31.3	8.3	26.1
1961	946,800	32.3	32.7	8.6	26.5
1966	1,085,350	33.8	32.3	7.6	26.3
1971	1,453,500	33.8	28.6	7.9	29.6
1976	1,941,000	35.9	22.8	8.7	32.5

Source: Adapted from U.S. Bureau of Mines, Petroleum Refining Information Circulars, in Pratt, 1980, p. 96.
*42-gallon barrels per day

Moreover, between 1950 and 1980, government quotas were set for imported oil and this action raised oil and gas prices with the effect of stimulating Houston's economy.[9] Houston became the oil capital of the world. By 1990, the number of manufacturing plants in Houston had increased dramatically and the industrial complex extended over 25 miles along the Houston Ship Channel (see Figure 4.5 and Tables 4.4[i] and 4.4[ii]).

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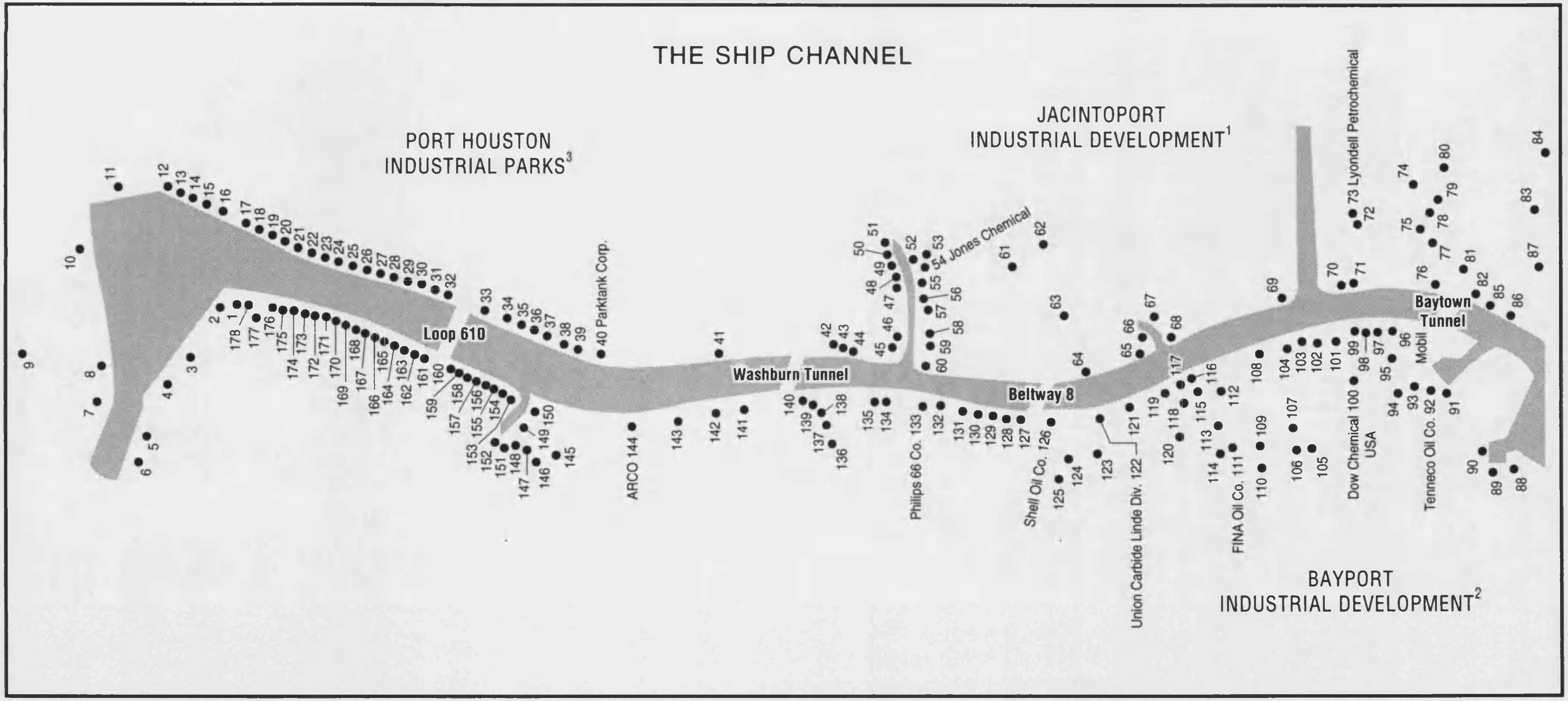
[7]Contradicting, in fact, the growth coalition's professed, but not practised, philosophy of free enterprise and no government intervention to preserve the business climate in the city of Houston (Feagin, 1988).

[8]These funds allowed the channel to be widened and deepened so that after 1914 ocean-going ships could use the port without reducing their cargoes (Thomas and Murray, 1991).

[9]Another important example of federal intervention was the decision to build the National Aeronautics and Space Administration complex (NASA) in Houston. Land for the NASA complex had been donated by Humble Oil, Exxon (Feagin, 1985).

Figure 4.5 Industrial development in the Houston Ship Channel



Source: Adapted from Port of Houston Authority (1991 b)

1,2 and 3: See Table 4.4(i)
Numbers 1-178: See Table 4.4(ii)

Table 4.4 (i) Industrial development parks in the Houston Ship Channel (see Figure 4.5)

1 **Jacinto Industrial Development**	2 **Bayport Industrial Development**	3 **Port Houston Industrial Park - East**
American Plating Co. Inc.	Amerigas	Big Mack Trucking Co.
Arrow Trucking	Airco Inc.	Cougar Inc.
Associated Pipeline Contrators	Air Products Mfg. Co.	Custom Transit Inc.
Bayou Petroleum Inc.	Akzo Chemie America	Houston S&M Trucking Inc.
Behring International Inc.	Arco Chemical Co.	Import Terminal Service
Bethlehem Steel Corp.	Atlantic Richfield Co.	Instel Corporation
Blue Water Maintenance	Bayport Investors	Maritime Services Co. Inc.
Brunelli Co.	Bayport Industrial Communications	Nissan Motor Corporation USA
Builders Transport	Baytank (Houston) Inc.	Texas Mooring Inc.
Cactus Pipe & Supply	Big Three Industries Inc.	
Cargill Inc.	Calgon Corp.	
Care Shipping Inc.	Carpenter Chemical	3 **Port Houston Industrial Park - West** 302-330
Carreta Trucking	Catalyst Resources Inc.	Camptell Trucking Inc.
Castle Metals	Chevron Chemical	Central Freight
Coastal Sulphur Inc.	Coastal Water Authority	Ceres Gulf Inc.
Creole Production Services Inc.Co.	Dixie Chemical Co.	Fretty
Dickson Weatherproof Nail Co.	E.I.Dupont	Gulf Import Auto Handling
Dundee Cement Co.	El Paso Products Co.	Gulf StatesToyota Inc.
Dynamic Products	Eval Co. of America	Intercontinental Steel Corportation
Enstar Engineering Corp.	Exxon Pipeline Co.	International Seamen's Center of Houston
Gasset Steel	FMC Corp.	International Stevedores
Gulf Chemical	Global Natural Resources Corp. of Texas	KAT-B Transcon Inc.
Haltermann Inc.	Goodyear Tire & Rubber Co.	Knox Truck Lines Inc.
Hill & Hill Truck Line Inc.	Graver Tank & Mfg. Co. Inc.	Merchants
Hollywood Marine	Gulf Coast Waste Disposal Authority	Mesaba Transportation Inc.
Houston Fuel Oil Terminal Co.	Haldor Topsoe Inc.	Norton Steel Products Co.
Houston Lighting and Power Co.	Himont USA Inc.	Port Container Industries Inc.
Houston Rail and Locomotive Inc.	Hoechst-Celanese	Port Trucking Services Inc.
Hutchison Hayes International Inc.	Houston Lighting & Power Co.	Port Warehouse Service Inc. & S&J Investments Co.
Inbesa America Inc.	ICI Americas Inc.	Port Warehouse Service Inc. & Storage & Processors Inc.
Intercontinental Service Co.	Kaneca Texas Corp.	Portway Transportation & Storage
International Tool and Supply Co.	Liquid Carbonic Corp.	Richardson Steel Yard
T.L. James & Co. Inc.	Lockheed Corp.	Sea Marine Warehouse
Koch Fuels Inc.	Lonza Inc.	Southside Services Inc.
La Porte Construction Co. Inc.	Lubrizol Corp.	Toyota Motor Sales USA Inc.
Levingston Industries Co. Inc.,	Main Tech Internaional	Volkswagen
Litho Strip Co	McKenzie Tank Lines	Willbanks Steel Corpl
Matlack Trucking	Montgomery Tank Lines	World Commerce Inc.
McDonald Brothers Trucking Co.	Petro United Terminals Inc.	Young & Co. of Houston
Mosher Steel	Petrolite	
National Marine Service Inc.	Pioneer Concrete of Texas Inc.	
Oil Tanking of Texas Inc.	Pipe & Valve Inc.	
Olin Corp.	Publicker Chemical Co.	
Patterson Truck Line Inc.	Republic Exploration Co. Joint Venture	
Petromax Chemical Exchange Inc.	Revak Enterprises Inc.	
Porta-Kamp Offshore	Rohm & Haas Bayport Inc.	
Powell Industries	Southern Ionics Inc.	
Pritchet Engineering & Machine	Southwestern Bell	
Sea Fabrication Inc.	Swisco Industrial Gases of S.E. Texas	
Sedco Inc.	Velsicol Chemical	
Sheffield Steel	Welchem Inc.	
Ship-Side Crating	Westinghouse Electric Co.	
TMC Services		
Triple B Corp.		
Tubular Services Inc.		
Vemar Inc.		
West India Shipping Co. Inc.		
Zapata Offshore		

Source: Adapted from Port of Houston Authority, (1991b)

Table 4.4 (ii) Industries in the Houston Ship Channel (see Figure 4.5))

1-113	114-122	123-178
1-4 Wharfs	114 Lextar	125 Intercontinental Terminals
5 Forest Products Distribution Warehouse	73 Lyondell Petrochemical	126 Shell Oil Co.
6 Coastal Co.	74 Exxon Chemical	127 Occidental Chemical Co.
7 Inspection Boat	75 Helmrich&Payne Intl. Drilling Co.	128 Tenn-USS
8 Wharfs	76 National Marine Service, Inc.	129 Carlon
9 The Crispin Co.	77 Hutchison Hayes Intl.	130 Tenneco Polymers
10 Observation Platform	78 Natural Gas Odorizing Div.	131 Georgia Gulf Corp.
11-16 Wharf	79 Exxon Chemical Americas	132 Ethyl Corp.
17 Houston Public Grain Elevators	80 Gulf Oil Chemicals Co.	133 Philips 66 Co.
18-33 Wharf	81 Hoesch Tubular	134 Air Products Mfg. Corp
34 US Coast Guard	82 J.M. Huber Co.	135 John Bludworth Marine, Inc.
35 USX Barge Slip	83 Houston Lighting & Power Co.	136 Ref-Chan Corp.
36 Ideal Basic Industries	84 Mobay Chemical	137 Brown & Root, Inc.
37 Dravo Basic Material Co.	85 Mobay Chemical Co.	138 Mobil Mining & Minerals
38 U.S Gypsum	86 Stauffer Chemical	139 GATX Terminals Corp.
39 Woodhouse Terminal	87 U.S. Steel Texas Work	140 Crown Central Petroleum Corp.
40 Paktank Corp.	88 Baytank	141 Simpson Pasadena Paper Co.
41 GATX Terminals Co.	89 Hoechst Celanese	142 Houston Lighting & Power Co.
42 Warren Gas	90 Petro United	143 Aristech Chemical Corp.
43 Amerada Hess	91 Railroad Ramp Point	144 ARCO Petrochemical Co.
44 Greens Port Terminal	92 Tenneco Oil Co.	145 Aristech Chemical Corp.
45 J.D.Hughes, Inc.	93 International Cargo Network	146 Denka Chemical
46 Greens Bayou Terminal	94 Chemline Corp.	147 Texas Petrochemical
47 Platzer Shipyard	95 Southwest Chemical Services	148 Goodyear Tire & Rubber Co.
48 Parker Brothers	96 Mobil	149 Tanker Dock 2
49 Densimix	97 P.P.G. Industries	150 Sims Bayou Tanker Dock 2
50 Armco, Inc.	98 Syngas	151 Gulf Coast Waste Disposal Auth.
51 Walton&Sons Terminal	99 Air Products Mfg. Corp.	152 Occidental Chemical Co.
52 Merichem Co.	100 Dow Chemicals U.S.A.	153 Manchester Terminal Co.
53 Reichhold Chemicals	101 U.S. Industrial Chemicals Co.	154 Hill Petroleum
54 Jones Chemicals	102 Lemn Corp. Terminal	155 Westway Trading
55 Penwalt Corp.	103 National Petrochemical Co.	156 South Coast Terminals, Inc.
56 Fermenta Plant Protection	104 Houston Lighting & Power Co.	157 Chemical Exchange Industries
57 Fireboat station	105 Ex-Im Freezers	158 Cargill Molasses
58 Intercontinental Bulk Systems	106 Aristech	159 Fireboat Station
59 Eisenman Enterprises, Inc.	107 Trammel Crow	160 Elco Shipside Elevator
60 Port of Houston Bulk Materials	108 San Jacinto Battleground	161 Occidental Chemicals
61 Dickson Waterproof Nail Co.	109 B.F. Goodrich Intermediates	162 Stauffer Chemical Co.
62 AMF Tuboscope, Inc.	110 Texas Alkyls	163 Shibley Ocean Industries
63 American Planting Co. of Texas	115 Intercontinental Terminal Corp.	164 Marine Industries
64 Oil Tanking	116 Rollins Environmental Services, Inc.	165 Newpartk Shipbuilding
65 Cargill Elevator	117 Parktank Corp.	166 Bludworth-Bond Shipyard
66 Inbesa Terminal	118 DSI Transports Inc.	167 New Terminal
67 Jacintoport Terminal	119 Rohm & Haas	168-175 Wharfs
68 Houston Fuel Oil Terminal	120 W.R. Grace & Co.	176 Hosuton Tank Storage
69 Falcon	121 Aristech Chemical Corp.	177 Jacob Stern & Sons, Inc.
70 Southwestern Barge Fleet Service, Inc.	122 Union Carbide Linde Div.	178 Pacific Molasses Co.
71 Glendale Boat Works, Inc.	123 Lubrizol Corp.	
72 Big Three Industries, Inc.	124 Goodrich Geon	
111 Fina Oil Co.		
112 Occidental Chemical Co.		
113 Interox America - Soltex Polymer		

Source: Adapted from Port of Houston Authority (1991b)

Massive defence spending on the Pentagon's production system and the military-industrial complex spawned new industries in the city such as hi-tech complexes and suburban office-commercial parks, 'Houston's greater ability to garner largesse from the federal government is a windfall passed out by the Pentagon' (Child Hill and Feagin, 1987, p. 174). In summary, 'cheaper production costs (weaker unions, lower wages), weaker physical and structural barriers to new development (no ageing industrial foundation) and tremendous federal expenditures on infrastructure facilities (highways) and high-technology defence industries' (Feagin and Smith, 1987, p. 168), contributed to Houston's growth.[10] Clearly, environmental protection could not become a priority in a city where the means to achieve growth and profit were unrestricted and uncontrolled, the national government actively encouraged these motivations, and, significantly, where the principal forces of growth were tightly linked to an international system of production and capital accumulation.

As established in Chapter 2, the thesis adopted the stance that sees the causes of environmental degradation in capitalism itself as the most appropriate to address environmental crisis and ill-health (e.g., Redclift and Woodgate, 1994; Redclift, 1987, 1992; Dickens, 1992; Benton, 1994), rather than views which turn to the market economy to cure the problems it brings about. Emphasis on the political and economic processes of environmental degradation is important because 'capitalist development transforms nature and the environment within a logic which needs to be understood in global terms' (Redclift, 1987, p. 47). The tendency has existed to depoliticize environmental issues at the international level, while considering resource conflict at the local or national level as other than environmental (Redclift, 1984). Crucial to any analysis of environmental degradation are the identification of the causal powers of the process of capital accumulation and the identification of the particular historical conditions under which internationalization of both capital and the local

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[10]Thomas and Murray (1991) have pointed out that Houston's production of crude oil made the area the supplier of one more cheap commodity for the national market; oil was added to cattle, cotton and timber.

environment occurred. Capital accumulation, and the current global dimension of it, is at the root of societal changes which cause environmental degradation.

4.3.3 *The International Economic Context of Environmental Degradation in Houston*

It is not sufficient to claim that capitalism has brought about environmental, and hence health, changes in Houston. In order to understand why a city like Houston has undergone particular environmental undermining, and also to suggest possible solutions, transformations in the world economy which are thought to have had recognized environmental impact in Houston will be briefly outlined. Local pollution in Houston is clearly related to the international capitalist economy.

The natural and social processes that have affected the environmental quality of the city (see section 4.2.2), and not least the health of the residents, can be understood when approached by a view which considers the economy beyond the local level (Feagin, 1988). 'Changes in cities are a result of global and local capital as well as resulting from state policy at local and national levels' (Feagin and Smith, 1987, p. 17). In fact, as a result of shifts in the world oil market in the 1960s and 1970s, scattered company operations around the USA were closed and consolidated in larger offices in a few key cities, New York, Los Angeles, Detroit and also in Houston (King, 1991; Feagin, 1985). Of the world's 35 largest oil companies in the 1960s, 34 had located major office and plant facilities in the Houston area.[11] Since the formation of OPEC in 1973, the city replaced its role of direct involvement in oil processing with a much greater emphasis on oil-related, often export oriented, services technology, financial policy, and control functions (King, 1991). Hundreds of national and international geological firms, drilling contractors, supply companies

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[11]Shell Oil located its US administrative headquarters there; Exxon concentrated more administrative and research operations; Gulf, Texaco, and Conoco located or expanded major national subsidiaries in Houston (Feagin, 1985).

and law firms together with 400 major oil and gas companies, were based in the city (Child Hill and Feagin, 1987). Substantial international trade passing through the Port of Houston linked Houston and cities in Latin America, the Middle East, and the Far East.

Houston's economic base was affected as much by international as by national events - the 1973-1974 OPEC price increase, for example, brought rises in profits for oil companies, boosting the Houston base. Conversely, a major recession affected Houston in 1982-1987 due to the decline in oil prices in the early 1980s, the construction of numerous large capacity refineries in the Third World including the Middle East and Asia, and the problems of declining oil production, oil glut and slowing of demand for oil in the USA (Thomas and Murray, 1991).[12] However, the economic recession in the 1980s did not result in a movement away from national and global oil and natural gas markets. Houston continued to provide raw materials, specialized services and markets for the global capitalist economy which have been qualified as essential in the new international division of labour (Feagin, 1985).

The city's economy from a global capitalist view, with its world-wide network of production, exchange, finance and corporate services, has been based on transnational practices (King, 1991; Feagin, 1988). Houston housed 11 top company headquarters in 1984, representing the ninth largest concentration of major multinational corporations in the world (New York housed 59 top firms; London 37; Pittsburgh and Hamburg, 10 each; Toronto 7).[13] Sklair points out that the transnational corporation is the major locus of transnational economic practices - the foundation on which service-related firms and a huge array of small to middle-sized commercial and industrial corporations have been grounded; and the transnational

[12]The impact of the world restructuring in the oil economy and in the manufacturing sector in Houston was profound (Feagin, 1988). The 1982-1987 crisis and reorganization in the world oil-gas industry were linked to 10% unemployment, over 1000 bankruptcies, oil refinery and other oil company lay-offs, and cutbacks in the petrochemical industry (Hill and Feagin, 1987, p 174).

[13]Houston had long been the world centre of oil technology. In the 1920s this meant little more than developing better drilling tools, but by the 1950s the industry was concerned with massive tasks such as designing and building off-shore drilling platforms (Thomas and Murray, 1991, p. 47).

capitalist class is the major locus of transnational political practices (1994).[14] Control of most of the factors which influenced the growth of the region's refining and oil industry was generally vested in the distant headquarters of nationally and internationally active corporations.[15] With the absence of top oil firm headquarters but a high concentration of major divisions of top oil firms (see section 4.2.3), the role of Houston, like that of Detroit, in the international division of labour has been a 'divisional command city' (Feagin and Smith, 1987, pp. 6-8; Feagin, 1985). Within the context of the international economy, the role Houston has fulfilled is that of an oil-specialist international city:

> *The world of modern capitalism is both a world-wide net of corporations and a global network of cities ... But most cities are not at the world command level; indeed, different cities occupy a variety of niches in the capitalist world economy (Feagin and Smith, 1987, p. 3).*

For Houston, the contamination of the natural environment has been concomitant with filling this privileged position in the international economy. This process of severe air contamination in Houston has clearly been ignored by local business people, international corporations, and also the national government. Since the city became the centre of a national and international economy, 'local concerns mattered less and less to the corporate leaders who ordered and controlled the direction of industrialization and who focused on national and international markets, but not on local matters' (Fisher, 1994, p. 3).

The thesis has argued that while there are general tendencies or causal processes in capitalist societies, they do not operate in isolation, but in combination with historical, social, and physical local circumstances (see section 2.8.1). The result

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[14]One needs to consider however that the power of large corporations and transnational banks is insufficient to explain their capacity for global control. The practice of global control, the work of producing and reproducing the organization and management of a global production system and a global marketplace for finance constitute the capability for global control (Sassen, 1991).

[15]The decision to expand a refinery took place in New York or Pittsburgh. The determination of regional wage rates was influenced by negotiations between union headquarters in Denver and national and international officials of the oil companies. From Washington came decisions affecting a wide range of refinery-related matters, from the size of the owner company to the volume and type of effluent discharges allowed (Pratt, 1980).

is 'variety and uniqueness with particular local combinations and development of the tendencies' (Massey, 1987, p. 120). It is the local combination of processes and events that is key. In summary, the appropriateness of the historically specific political-economy approach adopted in the thesis in the prevailing situation in Houston in the 1980s and 1990s is, therefore, absolute (see section 2.7.4). Economic growth as well as the globalizing tendencies of capitalism (Benton and Redclift, 1994) have been the most influential power in causing severe environmental degradation in Houston, and this has been supported by the generative, rather than reactive, role of the government in economic growth (Feagin and Smith, 1987). Capital influx has been kept unrestrained, with the absorptive capacity of Houston environmental systems quickly overwhelmed (Cherni, 1993). The next section moves on to examine the characteristics of present air pollution in Houston.

4.4 Characteristics of Air Pollution in Houston

The aim of this section is to establish the degree and type of current air pollution in Houston, the monitoring and control of which are carried out by four agencies: the federal USA Environmental Protection Agency (US EPA), the state Texas Air Control Board (TACB), the City of Houston Bureau of Air Quality Control (BAQC), and the private Houston Regional Monitoring (HRM). The section will focus on three aspects of air pollution characterization: ozone excess, as the main air pollution problem in the city, attainment of the six National Ambient Air Quality Standards (NAAQS) , and on the 'Pollutant Standard Index' (PSI) which relates to health risks. Under the national specifications, an air pollutant episode is described as any measurement that is higher than any of the six NAAQS without any other specification. The NAAQS are displayed in Table 4.5.

Primary standards are designed to protect public health; secondary standards to protect public welfare, that is, vegetation, materials and visibility. The standards are further categorized for different averaging times. Long-term standards specify an annual or quarterly mean that may not be exceeded; short-term standards specify upper limit values for 1-, 3-, 8- or 24 hour average time spans. Except for the pollutants ozone and PM-10 (particulate matter), the short-term standards are not to be exceeded more than once per year (US EPA, 1991, p. 2-1). There are many more pollutants which are recognized as having carcinogenic effects but for which national limits have not been set. Such are the so called Volatile Organic Compounds (VOCs), which are composed of 157 toxic pollutants and are emitted from sources as diverse as automobiles, refineries, chemical manufacturing, dry cleaners, paint shops and other sources using solvents (TACB, 1992b).[16] However, the Texas Air Control Board uses estimated guide-lines for many non-regulated chemicals.

Table 4.5 National Ambient Air Quality Standards (NAAQS) in effect in 1990

Pollutant	*Average Period*	*Primary NAAQS*	*Secondary NAAQ*
PM-10	Annual*** 24-hour*	50 ug/m^3 150 ug/m^3	Same as primary
Sulphur dioxide	Annual*** 24-hour** 3 -hour**	0.03 ppm - 80ug/m^3 0.14 ppm- 365ug/m^3 ------	0.50 ppm
Carbon monoxide	8-hour** 1-hour**	9 ppm 35 ppm	No secondary standard
Nitrogen dioxide	Annual***	0.053 ppm	Same as primary
Ozone	Maximum daily 1-hour* average	0.12 ppm	Same as primary
Lead	Maximum quarterly*** average	1.5 ug/m^3	Same as primary

Source: Adapted from US EPA (1990b, p. 2-2) and from Texas Air Control Board (1993a, p. 2).
* Not to be exceeded on more than three days over three years
** Not to be exceeded more than once per calendar year
*** Not to be exceeded

4.4.1 *Atmospheric Ozone Pollution and Industry*

Ozone contamination has reached high levels in Houston. In 1990, the highest measurement recorded was 0.22 ppm, and in 1980, it was 0.35 ppm when the

[16]Only the HRM corporation and another privately funded corporation, the Southeast Texas Regional Planning Commission networks monitor VOCs in Houston (TACB, 1992c). Unfortunately, their reports are not available to the public.

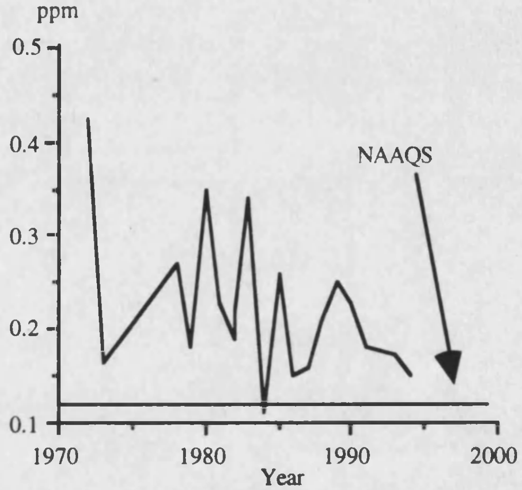
NAAQS=0.12 ppm (see Table 4.4). After Los Angeles, Houston was the second most polluted city in 1990 in the USA due to excess ozone concentration (BAQC, 1991). Houston is said to be a very distant second with only 52 days in excess compared to 137 days in Los Angeles (McMullen, 1989; TACB, 1992a). Nonetheless, when compared to cities with the next highest levels of ozone, it is evident that these are very far below Houston: Philadelphia with 17 days; Detroit, with 10 ozone excess days and New York with a maximum of 5 days (data from US EPA, 1991, table 5-3, p. 5-4). Recognition that the ozone problem is definitively worse in California than in any other US state does not invalidate the fact that even when the pollutant measures are smaller, other US areas are severely affected, particularly Texas:

> *The ozone problem may have had a long association with southern California but it is a very serious problem in other regions such as the Texas Gulf coast. Had it not been for the US EPA relaxation of the ozone standard from 0.08 to 0.12 ppm in February 1979, following strong pressure from the petroleum industry, many more tens of millions of people would be regarded as living in areas with unacceptable air quality (Elsom, 1992, p. 221).*

A valuable source of information for putting ozone contamination in perspective is the historical US EPA record of regional air pollution since official site-monitoring started in the 1970s. Air pollution reports for the Houston area reveal strikingly high levels of ozone, particularly near the refineries in the Ship Channel (see Figure 4.6). Also in the South-West of the city, ozone levels exceed significantly the national health guide-lines, but not by as much as in the Ship Channel area (see Figure 4.7). These findings strongly relate and confirm the historical results from the earlier surveys in 1923, 1956-1958, and the 1964-1966 survey (see section 4.2.2).

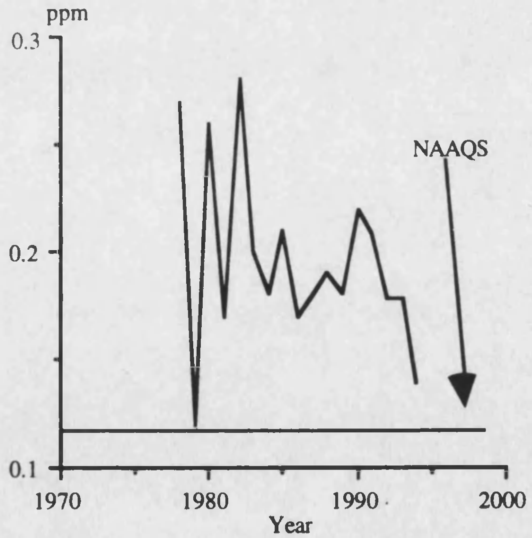
Ozone is a necessary and desirable component when it is in the upper atmosphere at heights of 5 to 10 miles above the Earth's surface where it partially blocks the sun's radiation. However, at ground level, high ozone concentrations present problems in urban areas and it is the most difficult and expensive air pollutant to control (TACB, 1987). A number of factors contribute to this difficulty. Unlike other gaseous pollutants, ozone is not emitted directly into the atmosphere. Instead, it is created by the action of sunlight on volatile organic compounds and nitrogen oxides.

Figure 4. 6 Measured ozone levels* in the Ship Channel area, Houston, 1972-1994**



Source: Data from US EPA Aerometrics Information Retrieval System, AMP 450.
*Ozone NAAQS= 0.12 ppm
**The monitoring site is located in 9525 Clinton Drive (see Figure 3.2).

Figure 4.7 Measured ozone levels* in the South-West area, Houston, 1978-1994**



Source: Data from US EPA Aerometrics Information Retrieval System, AMP 450.
*Ozone NAAQS= 0.12 ppm
**The monitoring site is located in 13826 Croquet Drive (see Figure 3.2).

Levels of ozone in Houston, as in Los Angeles or Mexico City, rise during sunny days with light wind speeds, primarily during the months from March through October. Ozone trends are strongly influenced by annual variations in meteorological conditions. For example, in the summer of 1988, which was exceptionally hot particularly in the east and north US coast, extreme rises in ozone levels were registered. In 1988, 101 areas in the country failed to meet the 0.12 ppm ozone standard (see Table 4.6). Moreover, ozone tends to be an area-wide problem with fairly similar levels of concentration occurring across broad regions. Therefore, because ozone is not simply a localized hot-spot problem, the view of its health effects has to incorporate this knowledge.[17]

Table 4.6 Highest peak ozone* concentration measured in selected USA metropolitan areas, 1988 and 1990.

City	*1990 Population (millions)*	*Max one-hour concentration ppm*	
		1988	*1990*
Atlanta, GA	2.7	0.17	0.15
Boston, MA	2.8	0.17	0.11
Chicago, IL	6.2	0.22	0.11
Dallas, TX	2.5	0.13	0.14
Denver, CO	1.6	0.12	0.11
Detroit, MI	4.4	0.16	0.12
Houston, TX	3.2	0.22	0.22
Los Angeles, Long-Beach, CA	8.5	0.33	0.27
New York, NY	8.5	0.18	0.16
Philadelphia, PA-NJ	4.9	0.20	0.14
Pittsburg, PA	2.1	0.16	0.11
Washington, DC-MD-VA	3.6	0.18	0.13

Source: Calculated from US EPA (1991) and US EPA (1990b).
* Each concentration shows the highest measurement recorded at any one site in each of the cities shown.

Industry and motor vehicles have been identified as the main sources of atmospheric ozone in Houston, most of which is made by VOC, oxides of nitrogen and sunlight. In fact, refineries, petrochemical and other industrial plants emit 54% of all VOC emissions in Houston. Mobile sources contribute 31%, while small localized

[17]The US EPA (1991, p. 4-9) claims that non-attainment boundaries may consider other air quality related information, such as emission inventories and models, and may extend beyond those counties with monitoring data to characterize more fully the ozone problem. For example, any population exposure estimates depend upon the assumptions and methodology used. In some cases there can be a wide swing in the estimate. While there were an estimated 63 million people living in counties where ozone levels in 1990 did not meet the NAAQS, there were an estimated 140 million people living in ozone non-attainment areas. These numbers are properly qualified in spite of such a large difference (ibid., p. 4-8).

sources (such as gasoline retailers and dry cleaners) emit 15% of total emissions (McMullen, personal communication, February 1992). This association is of fundamental importance for it points to the clear influence of industrial sources on the high concentration of pollutants in Houston. Furthermore, the industrial origin of persistent ozone pollution in highly transited areas in the city has been shown in an unpublished work carried out by the City of Houston BAQC (ibid.). Over 7 days a week, in a 10 years period between 1980 and 1990, the study compared the average number of days which exceeded the ozone permitted levels and the amount of traffic on a busy freeway located far from the industrial area in the Ship Channel. The study found that, while traffic count decreased significantly during Saturday and Sunday, the ozone average excess during these days remained as high as during the rest of the week. The only reason for air contamination to remain as severe on week-ends as during week-days was that oil refineries and other manufacturing plants in the Ship Channel operate during Saturday and Sunday. Industrial emissions travelling from the Ship Channel area were the source of persistent high ozone levels during the week-ends. The same source obviously contributes to the high concentration of ozone during week-days (McMullen, personal communication, 1992). However, relying only on ozone measures to assess environmental problems presents a number of difficulties. First, even if the exact effects of exposure to ozone could be scientifically identified, which they cannot, problems arise in determining the actual levels to which the general population may be safely exposed. Second, estimates can be made of the number of people who could potentially be exposed to the levels of ozone monitored each hour throughout the day. However, even on a day in the Houston area when numerous stations record high ozone values, there is a significant variation in the levels of ozone to which people might be exposed. Studies which consider spatial variability of concentration of pollutants are essential for the purpose of assessing exposure and understanding the severity of the health consequence (e.g., Cuzick and Elliot, 1992; Hatch, 1992; Caprio, 1975; see section 2.6). Third, present monitoring machinery can measure pollutants up to a certain altitude only. As a consequence, concentration of pollution above the technical limit cannot be assessed (McMullen, personal communication, 1992). In this sense, the actual levels of concentration of pollutants and hence of exposure remain a mystery. Therefore, full reliance on ozone excess to assess the problem of contamination and hence, of health, may not be sufficient. Neither measuring nor modelling includes the necessary variables to assess exposure nor to assess health risks (see section 2.5). To address this shortcoming, the thesis looks now into two other measures of air pollution, attainment approach and the PSI.

4.4.2 *Attainment of National Air Quality Standards*

'Attainment' and 'non-attainment' area are the criteria which reflect the degree of compliance with the nationally established NAAQS. Assessment of air quality under the national rules tracks two kinds of trends: air concentrations, based on actual direct measurements of pollutant concentrations at selected sites throughout the country; and emissions, which are based upon the best available engineering calculations. It incorporates a broader range of meteorological conditions and control strategy considerations (US EPA, 1991).

In 1990, Houston ranked first among seven Texas MSAs which violated national standards for ozone (see Figures 4.8 and 4.9). Houston was also second among 60 of 223 USA MSAs which exceeded the ozone NAAQS.

Figure 4.8 Comparison of peak ozone measurement* for Texas metropolitan and regional areas, 1990**

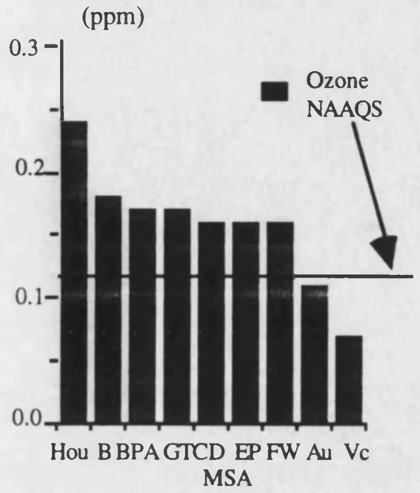
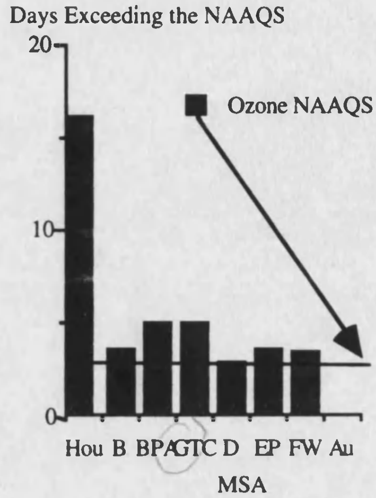


Figure 4.9 Comparison of highest number of ozone exceedance days for seven Texas metropolitan and regional areas, 1988-1990**

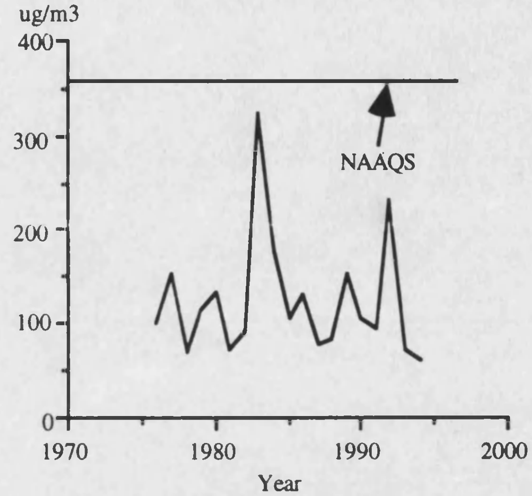


Source: Data from TACB, 1993a, p. 4.
*Each bar shows the highest measurement recorded at any one site in each of the areas shown
** Hou: Houston; B: Brazoria; BPA: Beaumont-Port Arthur; GTC: Galveston-Texas City; D:Dallas; EP: El Paso; FW: Fort Worth; Au: Austin; Vc: Victoria

In addition to ozone pollution, Houston has historically shown the highest measured sulphur dioxide levels in the state, despite the fact that no sulphur dioxide episodes have been listed for the state of Texas (TACB, 1993a). Nonetheless, high sulphur dioxide levels in two sites in the Houston Ship Channel area had been recorded by the HRM, the private network (TACB, 1992c, p. 5). As a result of high levels of sulphur pollution, a portion of the Houston Ship Channel area was considered for designation as one of non-attainment for sulphur dioxide (TACB, 1992b). Sulphur dioxide is produced by the burning of sulphur-containing fuels, from the smelting of metallic ores containing sulphur, and in the process of removing sulphur from fuels. In Houston, these processes take place in petrochemical plants located across the Ship Channel. Examination of historical annual records by monitoring sites revealed that the levels of sulphur dioxide had been much higher in the east, i.e., the location of the industrial and refinery area, than in the South-West side of the city (see Figures 4.10 and 4.11). Also the thesis household survey for the

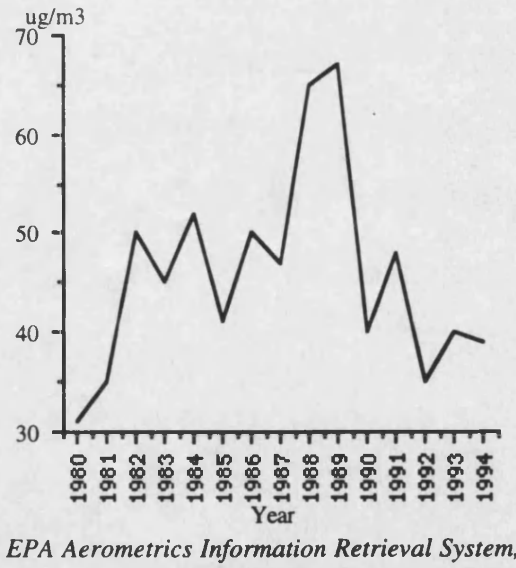
Ship Channel area reveals high reported air pollution in the Houston industrial area (see Chapter 7).

Figure 4.10 Measured sulphur dioxide levels in the Ship Channel area, Houston,* 1978-1994



Source: Data from US EPA Aerometrics Information Retrieval System, AMP 450.
*The monitoring site is located in 9525 Clinton Drive (see Figure 3.2).

Figure 4.11 Measured sulphur dioxide levels in the South-West of Houston,* 1980-1994



Source: Data from US EPA Aerometrics Information Retrieval System, AMP 450 .
*The monitoring site is located at 13826 Croquet Drive (see Figure 3.2).

As to oxides of nitrogen, several types are produced by high temperature fuel combustion, but only nitrogen dioxide has national standards. As a result of this limitation, the levels of nitrogen dioxide measured in Houston cannot reflect the real level of oxides in the atmosphere. The levels of nitrogen dioxide thus have consistently registered well below the NAAQS levels (TACB, 1992b, p. 3).[18]

Comparison of national air quality attainment in Houston and in other Texas and US MSAs is necessary because it indicates the relative degree of contamination in one particular city. However, these comparisons (1) do not indicate whether the pollutant standards themselves are adequate to safeguard the health of the population, and (2) do not reflect the effect of particular geographical distribution of air pollution within one MSA. Recognition of spatial variation of air pollution - as shown above for ozone and sulphur dioxide - is necessary not only because of the prospective impact on health, but also for two additional reasons. First, study of variation in pollution levels - together with other factors - may throw light on the appropriateness of permitted levels of air pollution; and second, this type of study provides clues about the connection between the type of economic activity and environmental deterioration.

4.4.3 *The Pollutant Standard Index and Health Risks Hazards*

The Pollutant Standard Index, PSI, simplifies the presentation of air quality data by producing a single dimensionless number ranging from 0 to 500 when 0 is good and more than 100 is unhealthy (see Table 4.7).

The PSI places maximum emphasis on acute health effects occurring over very short time periods (24 hours or less) rather than chronic effects occurring over months or years. It does not specifically account for damage air pollutants can do to animals, vegetation, and materials. However, increased PSI levels generally reflect increased

[18]Total suspended particulate, TSP, has been monitored in the Houston area since the late 1960s. TSP includes a broad class of chemically and physically diverse substances that exist as discrete particles over a wide range of sizes. However, the EPA changed in 1987 to apply only to small respirable particle of aerodynamic diameter of 10 microns or less, *PM-10*. The new indicator and the corresponding NAAQS were established based on the understanding that the smaller particles penetrate deeper into the respiratory tract, thus having a greater potential to cause adverse health effects. There have been certain areas in Houston that violated the original TSP NAAQS. With the implementation of the new NAAQS for PM-10, those areas have been designated unclassifiable for TSP. Consequently, none of the monitors has recorded a violation of the PM-10 NAAQS (TACB, 1992b).

damage to the general environment (US EPA, 1993). The index is primarily used to report the daily air quality of large urban areas as a single number or description word. Frequently, the index is reported as a regular feature on local TV or radio news or in newspapers (US EPA, 1991, p. 5-2). The PSI uses data from all selected sites in the MSA and combines different air pollutants with different averaging time, different units of concentration and, more importantly, with different national standards. The PSI is computed for PM-10, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide (US EPA, 1991; 1990b, p. 5-2).[19]

Table 4.7 The US Pollutant Standard Index and health hazard

INDEX RANGE	DESCRIPTION WORDS
0 to 50	Good
51 to 100	Moderate
101 to 199	Unhealthy
200 to 299	Very Unhealthy
300 and Above	Hazardous

Source: US EPA (1991, p. 5-1).

Examination of US EPA records between 1984 and 1993 reveals a remarkably high number of days when the PSI in Houston was greater than 100 (US EPA, 1994). Compared to other major US metropolitan areas, Houston had the second highest PSI>100 . Figure 4.12 displays average number of PSI > 100 between 1984 and 1993 for 10 out of 89 MSAs selected by US EPA (in 1990, there were 163 days in Los Angeles with PSI days > 100; 35 PSI > 100 days in Houston; 16 days in Atlanta; and 12 in Pittsburgh; calculated from US EPA, 1991, table 5-2, p. 5-3). These cities were selected here to represent highest, intermediate and low PSI > 100 days. There were 423 days with PSI > 100 over the period 1984-1993 in Houston; at least 12% of those were Very Unhealthy days. The highest number of PSI > 100 days occurred in 1987 and was 55. In Houston, 97% of the PSI days > 100 were due to ozone excess.

Although most days in the year are clearly within the healthy limits, the cumulative number of unhealthy days in Houston in a ten year period represents a

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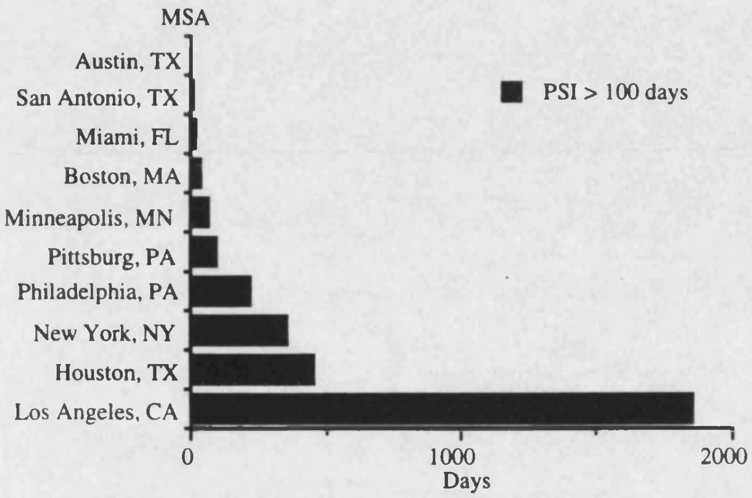
[19]Lead is the only major pollutant not included in the index because it does not have a short-term NAAQS, a Federal Episode Criteria or a Significant Harm Level.

source of concern. The city occupies the second place in the national PSI ratings, ranking below Los Angeles, CA., which, with 1851 days with PSI > 100 during 1984-1993, was rated the most unhealthy city in the USA. Although definitively Los Angeles is very distant from Houston with 423 days, New York, NY, with 359 days, and Philadelphia, PA, with 224, also score considerably less. These figures are illuminating when compared with cities with low number of PSI > 100, such as Miami, FL, 22 days; San Antonio, TX, 5 days; and Austin, TX, 2 days (calculated from US EPA, 1994; see Figure 4.12).

Figure 4.12 Cumulative PSI days greater than 100 in 10 selected US MSAs, 1984-1993



Source: data extracted from US EPA (1994).

The PSI provides useful information to the public. It also serves the purpose of qualifying cities by their overall environmental quality. Several problematic assumptions are implicit in the PSI analysis, however, the most important of which is probably that the monitored data available for a given area provide a reasonable estimate of maximum short-term concentration which may not represent the air pollution exposure for the entire area. If the downwind maximum concentration site for ozone is outside the MSA, this data area is not used in the PSI analysis. A further limitation is that PSI does not reflect geographical variations of concentration of air pollutants within one MSA. Local differences in pollution may be of utmost importance when studying the health impact of air pollution. Assessment of actual exposure and subsequent risk depends upon these measures. Finally, the PSI does not take into account the possible adverse effects of synergism, the effects of combinations of pollutants (US EPA, 1993). Each pollutant is examined independently. Combining pollutant concentrations is not possible at this time 'because the synergistic effects are not known' (US EPA, 1991, p. 5-7). This is likely to be a very important issue for the health effects. The information provided by the PSI and the attainment criteria are essential to determine present levels of pollution in Houston.

The next section moves on to demonstrate the coincidence of events over space: high levels of contamination, increased risk to localized population but also to the city in general, and huge industrial development. The discussion begins to address the theme of whether the priorities of governement institutions match the need to protect the environment and public health.

4.5 Coincidence of Events: Development and Risk

Within the advanced industrial countries, hazardous activities are found in what may be called 'pollution havens' such as petrochemical complexes or 'nuclear oases' such as Sellafield in the UK (Blowers, 1993, p. 792).

The purpose of the last section is to look into the spatial concentration of hazard and risk as the embodiment of two integrated social and physical processes, prolonged economic growth and rising environmental degradation in the Houston area. Colossal industrial growth and continuous port developments in Houston have been achieved as a result of vigorous national and international economic activity in the region, and supportive government policies. Undoubtedly, this configuration contributed to make Houston the USA's 'energy capital' and 'pearl of the Sunbelt', and not least, to its occupation of a privileged niche in the global economy (Feagin, 1985, 1988) (see section 4.2). The combination of the city's high concentrations of air pollution, and unregulated economic growth in Houston suggests a particular spatial structural pattern of exposure and risk. The section examines the pattern of residential settlement and of industrial development in the Houston Ship Channel area in particular, briefly outlines the spatial character of exposure to hazardous materials and accidents, and the current urgency of the pollution problem in Houston in general is assessed from the results of three regional surveys. It is also argued that, in spite of the fact that exposure to structural hazard is apparently highly localized in the Ship Channel area, there is an overall growing concern for the state of the natural environment which does not seem to be restricted to the most affected areas. This argument is supported by regional surveys on residents' views on the environmental crisis.

4.5.1 *Spatial Integration of Industrial and Human Settlements in the Ship Channel Area*

The origins of population settlement in this area date back to the decades of railroad growth in the nineteenth century when the first industrial areas in Houston were those concentrated along the railway and related machine shops in the north-eastern and eastern sectors of the city (Feagin, 1988). A shipping channel was originally dredged in 1857 in the east-side of the city to improve poor and shallow port facilities. With the expansion and development of the Ship Channel in the first decades of the twentieth century new industrial development grew up, running east from the downtown area along the Ship Channel. From the 1920s to the 1940s the eastern side of the city was the location of the vast bulk of oil refining, petrochemical, and metal-related plants and for developing port facilities (see section 4.3). Nonetheless, residential areas developed in the vicinity of the Ship Channel well before the development of both the oil business in the beginning of the twentieth century and the rise of petrochemical manufacturing in the 1920s.[20]

At each stage of development, whole Houston neighbourhoods were organized around the various types of economic activity (for example, railway workshops, cotton exports, and so on). Large sections in the east of the city have remained fully residential until the present day. In fact, new residential development has also taken place in the east. Apartment complexes and expensive houses were built in the last 20 years despite the fact that most suburban (i.e., far away from downtown) development in recent decades has taken place on the western and northern sides of the city (Feagin, 1988). Both detached houses for middle and upper income groups and low standard apartment complexes for the deprived are found in the east side of the city. In the 1990s, residence and industry have remained in close proximity to each other (see Plate 4.7).

The number of manufacturing plants operating in the Ship Channel is huge. Industries and refineries extend over some 25 miles (see Figure 4.5). The Houston MSA has 3,310 plants with more than 200 chemical plants alone (Greater Houston Partnership, 1990b). This represents an extraordinary increase from the some 420 manufacturing plants of all sizes found on the eastern side of the city in the early 1930s (Feagin, 1988). For example, Exxon Chemical, Hutchison Hayes International, Inc., Gulf Oil Co., Chevron Chemical, Exxon Pipeline Co., E.I. Dupont, ICI America Inc., Velsicol Chemical, Goodyear Tire & Rubber Co., Sheffield Steel and Phillips Co. are only a few of the many petrochemical and other industrial plants located there (see Tables 4.4[i] and 4.4[ii]). In addition, the Ship Channel is the site of one of the 10 largest ports in the world. By the mid-twentieth century, the Port of Houston was already one of the world's largest industrial

[20]In addition, an intricate underground system, the so-called 'spaghetti bowl', consisting of several thousand miles of product pipeline, connects some 200 chemical plants, refineries, salt domes, and gasoline processing plants crossing along the Texas Gulf Coast and the city of Houston (Greater Houston Partnership, 1990).

concentrations. The port ranks first in the USA in terms of foreign water-borne commerce and second in total tonnage (Port of Houston Authority, 1995; see section 4.2.2). The Port of Houston, the Ship Channel and the Houston-Gulf Coast region contain over 43% of the USA's basic petrochemical manufacturing capacity and more than 45% of its capacity for many first-stage derivatives. These are the present surroundings of large residential areas in the east side of the city.

Plate 4.7 The upper-hand of the oil establishment is manifestedly shown in this welcoming adverstisement to a popular residential and heavily industrialized neighbourhood. Ironically, it has been painted on a container of flammable material by a well-known petrochemical company and it welcomes drivers to one of the most highly polluted areas in the USA.

Continuous expansion of the Port of Houston and the growth of industrial activity along the Houston Ship Channel have imprinted a distinctive character on the Houston landscape, on the city air and, in particular, on that of the east side of the city. The area around the Ship Channel exhibits signs of both economic growth and environmental ruin. Extensive petrochemical establishments have created a skyline of smoking-chimney stacks, and a strange land surface populated by scattered huge oil and gas containers. This sight prevails along main motor-ways in the east of the city, but also well into secondary roads in residential areas. A striking feature of this area is the air pollution, which cannot but be noticed due to its distinctive sulphuric stench.

Often, low white clouds of toxic material emitted by the refineries cover the area. The petrochemical plants are not located at 'prudent' distance from residential areas. At times, air pollution can be very strong, and the stench unbearable, in particular in the surroundings of the refineries in the Houston Ship Channel. Visibility is often impaired by the low whitish clouds of sulphur and other pollutants. Although fumes are more pungent near the sources of emission, pollution reaches other parts of the city as well.

4.5.2 *Accidents and Hazardous Exposure*

Considerable environmental damage has accumulated since oil was first found and extracted in 1901. Residents, especially those living in the Ship Channel area, have continually borne the indisputable pollution burden of rapid and unrestrained economic growth. Residents are actually exposed to pungent odours from the refinery process, noxious clouds of hydrocarbon gases, and accidents such as explosions and leakage in petrochemical plants. For example, two massive explosions, in the ARCO Chemical Co. in November 1990, and another in the Phillips Petroleum Co. in October 1989, took the lives of 40 workers and 'showered neighbours with debris' (Grandolfo, 1989, p. 1). Beyond both the initial shock that residents suffer from being in such close proximity to an explosion, and the unknown long-term health effects, damage extends to destruction of cars in the vicinity, house foundations, and shattered windows panes (Bardwell, 1989; Pearson, 1990). Indeed, the dangerous effects of such accidents are borne mainly by the local residents:

> *Raúl Perez had grown accustomed to the noise and stink from the Houston Ship Channel petrochemical plants. But Monday he heard a distant sound that sent a chill up his spine. 'I was out there when I heard a rumbling at the Phillips plant', he said. 'It wasn't like anything I'd ever heard before, it was eerie. The next thing I knew - boom'. The force of the explosion - several miles away - sent the screen door slamming on his wife and him reeling for cover as a black mushroom cloud rose over the tiny frame houses just north of interstate 10 near*

Galena Park. Then the rain came. Shards of metal swirled in the dark sky and chunks of pipe insulation hurtled to earth ...' (Grandolfo, 1989, p. A-11).

Apart from oil-related explosions, gas leakage represent a further grave environmental hazard associated with petrochemicals. For example, in September 1990 residents in Deer Park were asked to stay indoors because of a leak of high-pressure gas from the Shell Oil Co. refinery (Byars, 1990). The health effects of industrial accidents involving environmental hazards, however, have not been taken seriously by the authorities responsible for public health and environmental quality. For example, the only warning that the government issued after a gas leak in 1990 was that residents were at potential danger from skin, eye and throat irritations. Clearly, the risks of more severe short-term reactions such as headaches, sickness and respiratory difficulties are coupled with the possibility of incurring longer term ill-health due to the development of respiratory problems and/or prolonged weakness. Such consequences have gone systematically unacknowledged by the authorities.

4.5.3 Residents' Views on Local Environmental Pollution in the 1990s

The thesis has followed the assumption that whilst knowledge from the natural and social sciences is necessary to assess the state of the environment and the effects on the population, the recognition of local problems by the affected residents is integral to shaping an understanding of what is wrong with the environment and the economy, and to proposing policies related to environmental protection and economic development. As discussed in Chapter 2, environmental problems have been solved by traditional decision-making often heavily shaped by scientific analysis and judgement. These kinds of decision are vulnerable to two major critiques. First, they play down the consideration of affected interests in favour of 'objective' analysis. Second, because they rely almost exclusively on systematic observations and general theories, they denigrate the local and anecdotal knowledge of the people most familiar with the problem (Renn *et al.*, 1995).[21] The purpose of this section is thus to examine the problem of environmental pollution in the eyes of Houston's population in general as it emerges from three regional surveys, the thesis APCHS, the Houston Area Survey (HAS), and the Texas Environmental Survey (TES) (see Appendix C.1).

The findings of the three surveys, the APCHS, HAS and TES, suggested that environmental quality in the city was very poor, that economic activity was directly implicated in causing prolonged air and water contamination, that the laws to protect the environment and to condemn polluters were insufficient, and that emission of recognized carcinogenics was highly feared. The surveys neatly pointed to the structural origin of environmental problems and highlighted the overall impact of pollution on the population.

Reflecting the findings of the Houston and Texas surveys, the responses indicated a growing belief that the city's environmental 'challenges' required sweeping changes (Klineberg, personal communication, February 1992). Houston residents had always reserved their lowest ratings for the city's efforts to control air and water pollution, but the negative vote in 1991 jumped 10 points beyond all previous ratings, to include fully 80% of all respondents. In 1985, 42% believed that people would be able to solve Houston's environmental problems through better technologies alone. By 1991 only 28% agreed with such a suggestion, while 69% said they would also have to change their way of life (up from 53% six years earlier). The HAS showed that in 1990, 73% wanted the city to provide all Houston households with curbside recycling facilities, 'even if it were cheaper to continue using the Houston landfills for another few years' (Klineberg, 1991, p. 27). Emission of cancer-causing chemicals above permitted limits was considered a criminal act by 88% of respondents (TES), who also voted for the individual responsible to be subject to prison. It was not expected that Texans would be overwhelmingly committed to environmental

[21]Furthermore, Renn *et al.* (1995) argue that traditional decision-making suffers from a lack of popular acceptance and risks producing outcomes that are incompetent, irrelevant, or simply unworkable (p.1). Some critic:sms of present policies to protect the environment have emerged (FoE, 1995; Lean, 1994; Ashton, 1993; Draper, 1991).

protection, 'given the public policy of the state, but when Texans were asked in the privacy of their own homes over the telephone how they see the world, they are unmistakably committed to environmental protection' (Klineberg, 1990b, p. 28).

Strong and growing interest of the residents for the environment emerged from the three surveys. Practically one third (32%) out of the 300 households interviewed in the two study areas mentioned air pollution as the main problem affecting their everyday life. Stronger regulation of polluting industries was favoured by a large majority of Texas residents who absolutely refused to trade-off economic development and environmental protection (Klineberg, 1990b). This is a striking finding given the context of rapid economic growth and successful business climate which has dominated the development of the city. If anything, the findings showed a prioritizing of for environmental concerns over economic issues (Klineberg, 1990a). For example, 68% of respondents rejected the idea that 'jobs will be first, and pollution second', and 77% opposed accepting a new plant that would create 1,000 new jobs but also caused substantial increase in pollution. Moreover, 65% said too little was spent nationally on 'improving and protecting the environment'. Stronger government regulation of industrial pollution was favoured by 84% and 83% supported a state law mandating deposits on recyclable glass bottles.[22]

While it was evident from the surveys that environmental problems had become an important focus of attention, the Houston and Texas surveys also indicate that economic growth has still remained integral to Houston's own world-view of development. When asked which of two strategies would be more effective in encourage economic development in Houston, 43% called for 'raising taxes to improve education and public services', but a majority of 51% opted for 'keeping taxes low'. In this way, by supporting a policy of low investment in public welfare, the city can continue offering an attractive business atmosphere, and hence, causing

[22]The APCHS showed, however, that considerable concern for environmental issues did not mean that residents actively participated in environmental protection related activities. The number of households that reported any type of involvement was very low.

more environmental pollution. A further obstacle to the generally expressed willingness to accept higher taxes for environmental protection was the widespread opposition to raising gasoline taxes (62%) (Dawson, 1990).[23]

In spite of prolonged support for business promotion, residents in the Houston area had reached new heights in long-term concern for the environment as the proportion of Houston residents who demanded more money for environmental protection jumped to 66% (Dorning, (1990). Krause (1990) claimed that the responses obtained in the Houston and Texas surveys gave grounds for the claims that there are clear signs among Texans of an emerging environmental consciousness. Also, residents who acknowledged the vulnerability of the natural environment to human intervention showed wide concern about the problem of global warming and placed the deterioration of the Earth's environment second only to international drug trafficking among the most serious long-term threats to the American people.

In summary, different types of knowledge are appropriate to different functions and contexts. But these contexts are not mutually exclusive but overlapping. In reality scientific practice embraces several types of knowledge, including some which are generally excluded as non-science or even anti-science by scientism (Sayer, 1992). Three conclusions can be drawn in this section. First, although machines can measure the concentration of pollutants (see section 4.4), they cannot identify the actual impact of air pollution on an area or on the population. Second, a biological approach to air pollution and health is useful because it focuses on the physical manifestations of the ecological impact and the mechanisms which trigger health changes. However, it leaves out the historical setting and structural references which are necessary for an understanding of why the biological relationship between air pollution and ill-health takes place at a certain place and time. Therefore, whilst historical knowledge of political and economic processes is essential, residents' views are very important to define present trends. Furthermore, if the survey is carried out

[23]The researcher does not want to imply that raising taxes for energy consumption is the only appropriate way to reduce the levels of air pollution in cities.

with causally related groups of people, as in the APCHS, it can be instrumental not only in uncovering the extent and character of the damage, but also in revealing causally relevant information. Hence, the last conclusion. Residents' views gathered in the environmental surveys clearly indicate the practical consequences of long-term structures of economic growth. Significantly, they also point to the inappropriateness of the environmental legislation. Historically, the severe impact of air pollution on human health, rather than anything else, has dictated the need for change in the legislation of economic activity and of air pollution control (see Chapter 1). Therefore, examination of the regulatory system, as much as the knowledge that people provide today on the effects of air pollution, is necessary to understand the conjuncture of air pollution, economic growth and ill-health.

4.6 Conclusion

The character of Houston in the 1990s is undeniably potentially dangerous, and particularly so for residents of the east side. There is a clear dominance of spatial patterns of risk due to hazardous exposure in the industrial area. A spatial coincidence of economic trends, environmental degradation and high health risks emerged from the analysis in Chapter 4. This does not alter the fact that environmental degradation has become the concern of a large number of people, who may or may not live in the most polluted areas, as attested in the regional surveys. What this means is that the extent of the problem of hazardous environment is perhaps larger than previously thought.

Throughout the twentieth century, Houston has become increasingly important as a world energy-related centre with consistent population growth and city expansion mirroring the city's development. The steady development of the city - miles of chemical plants, impressive buildings, shopping centres, and luxurious neighbourhoods - is only the most visible result of economic growth. A less visible but no less significant result has been the deterioration of the natural environment. In Houston the finite absorptive capacity of the physical environment and the natural threshold of humans to withstand the impact of industrialization have long been ignored in the rush for profit-centred activity. The ultimate consequences of this type of growth have been undeniable massive private wealth for a few, widespread poverty, and hazardous air (and water) for all.

While general trends of economic growth and the advance of the internationalization of capital seem to affect equally many regions in the world, the implications for both the city's environment and its population are substantially different, depending to a great extent on historical, structural, institutional and climatic factors. Houston is the US centre for its hitherto largely unregulated oil-based economy. Over time, initially from ignorance and lately for economic reasons, the strategies of growth have shown scant regard for the human and environmental element in the economic equation. In the 1990s, the degradation of the natural environment in and around Houston, particularly in the Ship Channel area, is such that living conditions for substantial numbers of the population are too often intolerable, their health and that of their children being sacrificed to the capitalist ethos.

Economies at the global, national and local levels are intimately intertwined in Houston under the common goal of economic growth. This process has had three main characteristics. First, the relationship between the natural environment and economic growth in Houston has been subsidiary in the sense that it operates in the global context of the international economy, adapting itself to changing general macro-economic conditions and to the international division of labour. Second, this relationship has been functional because economic growth in Houston was favoured by local economic agents who recruited financial and political support from the national government in order to promote a prosperous business climate in the city and in this way to foster capital accumulation on a large scale, particularly in the energy sector. Thirdly, the relationship in Houston has been contradictory because while economic growth created the conditions for the proliferation of massive wealth and prosperity, it also seriously damaged the natural environment, and hence, it put the population at risk.

Clearly, it is essential yet insufficient to identify that the capitalist economy causes local pollution. The next chapter moves on to address the local structures that account for the coincidence of events that emerged from this enquiry. Chapter 5 will begin to explain the role of regulatory structures and institutions in Houston.

CHAPTER FIVE

ENVIRONMENTAL AND PUBLIC HEALTH REGULATORY STRUCTURES

5.1 Introduction

The aim of Chapter 5 is to analyze two macro-structures, industrial pollution control and the delivery of health care in Houston, for their likely effect on the emergence of environmental problems and their influence on the current state of Houston public health. Whilst Chapter 4 revealed spatial coincidence of economic growth, high levels of environmental degradation, and health risks, Chapter 5 begins to account for them and explains how the regulatory institutions do not correspond with the degree of environmental contamination and public ill-health. As discussed in Chapter 3, examination of pollution control and provision of health care is necessary to arrive at an understanding of continuous environmental degradation, and hence, to the relationship between child ill-health and air pollution in some sectors of the city. It is expected that the implications of the way that these institutions work will be reflected in the actual character of air pollution as described in Chapter 4; and that some indications of their impact would emerge in the official statistics of public health. Chapter 5 is framed by the critical realist approach developed in Chapter 3. The environmental and health institutions, which are practically non-observable, are abstracted in order to distinguish their attributes and powers in the relationship between child ill-health and air pollution.

It will be argued that neither the protection of environmental quality nor the safety of the population has been a political priority in the face of continuous economic growth. In order to develop the argument of the chapter, three interrelated aspects of the problem will be addressed. First, the delayed emergence of nation-wide regulatory control is briefly reviewed, the regulation of industrial emissions is examined, and the legal commitment in the environmental regulation to protect public health is discussed.

Second, the limitations of the US health system are highlighted and the provision of health care, particularly in Houston, are examined. Finally, the state of public health is thoroughly reviewed.

5.2 Regulatory Response to Increasing Air Pollution

This section argues that the emergence of federal and state legislation for the protection of the environment reflects the conflicting relation between traditional commitment to economic growth, regardless of the consequences, and an attempt to guard the environment from further damage. It is shown that, historically, regulations to control the emission of toxic materials are weak and that this is indicative of prevailing pro-growth forces in the region. The section evaluates the strength of the government commitment to protect health within present regulations for controlling emissions.

5.2.1 *Emergence of Environmental Protection*

> *An effective nation-wide pollution control programme was opposed by very well organized and wealthy political lobbies of industry ... In Houston, restraints on rapid growth and caution over the rights of property owners would have been required to deal with oil-related damage to the environment (Pratt, 1980, p. 243).*

In the face of increasing air and water contamination from the cumulative impact of half a century of growth in industry and population in Houston (see section 4.2), pollution could no longer simply be ignored and more forceful means of implementing solutions were sought. Throughout the 1916-1941 period, oil industrialists in Houston had taken some initiatives to control the pollution, mainly of water, resulting from their activity. However, these had little impact on pollution control during the period because 'while a small group of researchers looked for answers to basic questions involving the treatment of water discharge, a much greater industry-wide research effort developed new techniques of production' (ibid., p. 238). In Houston, from 1901 until the 1960s, several state agencies - under-funded and understaffed as they were - were at the centre of public initiatives to control air pollution. Pratt argued that each of the existing agencies reacted to pollution as a minor problem, and 'although pollution sometimes became a threat to public health, local and state public health departments had many more pressing demands on their resources' (ibid., p. 231). Perhaps even more significant than the general lack of resources was the absence in the early years, as throughout most of the century, of even an under-funded public body with a specific and overriding institutional mandate to control pollution.

Pollution control in Houston was influenced by new federal laws throughout the 1950s and 1960s.[1] A US national approach to the problem was stimulated by the extreme six-day smog episode in Donora, Pennsylvania in 1948 (which caused 6,000 cases of illness and 20 deaths), and also by later smog and deaths episodes in London in 1952, and in New York in 1953 (see section 2.2).[2] The first national air pollution legislation in the USA, the 1955 Air Pollution Act, marked the beginning of federal involvement in a policy-initiating role, despite the fact that it only provided research and technical assistance, and the states and local governments were left responsible for pollution control at the source (Elsom, 1992).

In Houston, a gradual emergence of public leadership in pollution matters occurred only in the early 1950s when a group of citizens who lived near the Houston Ship Channel began a private campaign to reduce pollution through meetings with

[1]Many US communities had experienced severe air pollution prior to the 1940s, but control measures were largely limited to the passing of local legislation or to private litigation. In Los Angeles, smog was a problem from the 1940s, because emissions, principally from motor vehicles, oil refineries and back-yard incinerators, were converted to eye and nose irritating pollutants by photo-chemical reactions. It was not until the California legislation of 1947 that a state law tackled air pollution other than dense smoke, and not until 1952 that the state of Oregon introduced the first comprehensive state air pollution control legislation (Elsom, 1992).

[2]In Britain, only after around 4000 people died in the 1952 London sulphur pollution episode (the result of coal burning), was the first Clean Air Act passed in 1956 (see section 2.2). Since then, European and UK legislation have tightened considerably controls on air pollution from the so-called 'stationary' sources of homes, commerce and industry (Ball and Bell, 1994).

local industries. They sought to extract voluntary promises under the threat of court action; there was no public agency other than the courts to which they could turn. Their protests generated pressure for the creation of such an agency and encouraged the formation of an air and water pollution control section in the County Department of Health. This had only limited power to force reduction in discharge. Not until 1961, was the first state pollution control agency created, the State of Texas Water Pollution Control; and in 1965, the Texas Air Control Board (TACB) was brought into force. However, private organizations and the large oil companies retained a strong interest in imposing their own air and water quality standards on these public institutions, and the oil firms did not easily surrender their traditional autonomy in this area. In its early years, 'the board did not hamper the growth of industry or of pollution' (Pratt, 1980, p. 243). Indeed, programmes of local air pollution control were far from adequate (Krien and Ursin, 1977).

The US Air Quality Act of 1967 promulgated for the first time the acceptance of responsibility by the federal government if local control agencies failed, and required the states to establish air quality standards consistent with federal criteria. Health appears as a major priority of the Air Quality Act of 1967: 'to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population ... to insure that air pollution problems will in the future, be controlled in a systematic way' (Bach, 1972, p. 104). The Act still left the primary responsibility for air pollution control to the states and local authorities but required the federal government to intervene if necessary.

In contrast with earlier times, the environmental movement in the USA, peaking in 1969 and 1970, provided the political muscle necessary to counter the lobbying by industrialists. It resulted in the enactment of the innovative and sweeping Clean Air Act of 1970, marking the beginning of the present era of pollution control policy (Elsom, 1992). Uniform national air quality standards were set to protect public health and welfare (the NAAQSs; see section 4.4.2). In 1970 the agency was renamed the Air Pollution Control Office, and began to operate within the newly established

Environmental Protection Agency (EPA).[3] Nonetheless, quality standards have been flexible to the extent of leaving health objectives out of their scope. In fact, as a result of non-attainment of required national standards and continued pressure from petroleum industrialists, the Clean Air Act was subsequently relaxed and weakened during the late 1970s (ibid.). For example, the maximum allowable ozone concentration was increased from 0.08 to 0.012 ppm in 1979 - which is the present NAAQS, and sulphur dioxide emission requirements for major sources were relaxed in 1981 during the Reagan administration.

Having briefly traced the historical emergence of the US legislation to protect the environment, we move on now to examine the current measures that control industrial pollution in Houston.

5.2.2 *Regulation of Industrial Emissions in Houston*

The US regulatory approach is rule-oriented, normally employing rigid and uniform standards, there is executive and judicial scrutiny of regulators and the use of best available technology rules are favoured (Vogel, 1986). In Houston, most government regulatory work to limit public exposure to toxic air takes the same basic approach: measurement or calculation of the concentrations to which the public can be exposed; review of information on the effects of each chemical on animals or persons at concentrations that are orders of magnitude higher than the ambient levels; and determination of the regulatory requirements (TACB, 1992e, p. 1). To control and regulate air pollution in Houston, the Texas Clean Air Act (1967) requires the use of best available control technology (BACT) for all new and modified sources of air contaminants; and emissions fees. The rationale behind the use of BACT by the state

[3]Also Britain was setting national regulations by the same time. Although Britain can boast what is normally considered the world's first national public atmospheric pollution control agency in 1863, the Alkali Inspectorate, the fact that London air quality was monitored in the beginning of the century, and that in 1935 the first measurement network was set up to monitor SO_2 and other pollutants, regular monitoring in the UK only began in 1971. The character of this law was reactive and sometimes had little to do with environmental protection (Ball and Bell, 1994).

agency, the TACB, rather than quantitative risk assessment, is that part of the difficulty in setting and using exposure standards comes from the fact that a numerical standard implies that a public exposure at 90% of the standard is acceptable while exposure at 110% of the standard is not. Even if there is a level below which no adverse effects occur, there is a substantial uncertainty in determining that level. Moreover, the state-of-the-science does not allow quantitative risk extrapolation to the exposure levels normally encountered in ambient air.

Typically, regulations which target reduction of toxic emissions do not question the nature of the activities which give rise to air pollution, and this is reflected in the market approach that dominates the field of emissions control. For example, despite Houston being a non-attainment area (see section 4.3.2), new sources of pollution can be built providing that, first, the proposed plant has installed pollution control technology which ensures the lowest achievable emission rate (ibid.); and, second, that the proposed emissions are offset by reductions in emissions from existing sources in the area (the 'emission offset' policy). The policy - sanctioned in 1976, and integrated in the Emissions Trading Policy of 1982 - recognizes that air is a scarce resource and uses market forces to accommodate growth without increasing total pollution. Sponsors of a proposed new plant are required to offset the pollution which would result from their plant by: (1) reducing emissions from their own plant in the area; or (2) paying another company to reduce its emissions in the area; or (3) purchasing an old plant in the area and simply closing it down; or (4) purchasing emission credits, if available. Offsets create an unofficial market in pollution or emission reduction credits (Elsom, 1992).

This regulatory system allows a degree of flexibility and the reviewer may consider information such as operating schedule, adjacent property, and types of health effects associated with each substance. Also, an emission fee, if applicable, must be paid.[4] Further flexibility is reflected in the 'bubble' strategy introduced in

[4]The fee for fiscal year 1992 was set at $3 per ton for regulated pollutants at the affected account, including, but not limited to, those emissions from point and fugitive sources during normal operations. Although certain fugitive emissions are excluded from applicability determination

1979, and incorporated into the Emissions Trading Policy of 1982. This gives plant managers considerable freedom in finding the cheapest, most efficient way of meeting pollution control standards. The bubble strategy considers the plant, or a series of plants, to be enclosed in a bubble and the EPA sets limits on the total discharges of each type of regulated pollutant, leaving it up to the plant manager to decide how to reach the goals. Trade-offs between sources of pollution within the bubble must involve the same pollutant such that plants are not allowed to offset, say, reduced sulphur dioxide emission against expensive controls on other toxic emissions (ibid.).

Established industrial plants are controlled in the following way. Any person owning or operating a source of air contaminants must comply with the requirements of EPA for the national ambient air quality standard of the six regulated air pollutants (see section 4.4.2). The TACB states that 'no person shall discharge from any source whatsoever one or more air contaminants or combinations thereof, in such concentration and of such duration as to cause air pollution' (TACB, 1987, p. 14). If any company does so, owners must, upon request by the Board or the Executive Director, 'conduct sampling to determine the opacity, rate, composition and/or concentration of such emissions' (ibid., p. 15). The TACB establishes that in an area where a cumulative effect occurs from the accretion of air contaminants from two or more sources on a single property or from two or more properties, such that the level of air contaminants exceeds the ambient air quality standards established, and each source or each property is emitting no more than the allowed limit for an air contaminant for a single source or from a single property, 'further reduction of emissions from each source or property will be made' as determined by the Board (ibid., p. 13).

According to the TACB, these procedures have major advantages for the protection of public health because: (1) the BATC requirement minimizes direct public exposure to all chemicals emitted from permitted facilities, whether or not the

purposes, all fugitive emissions must be considered for fee calculations after applicability of the account has been established. The fee for fiscal year 1993 was set at a minimum of $5 per ton but the fee for fiscal year 1994 and later years is set at a minimum of $25 per ton (TACB, 1987).

chemicals are toxic enough to require regulation; and (2) since virtually all chemicals react in the ambient air to form other compounds, some of which are more toxic than the original emissions, minimizing all chemical emissions also minimizes public exposure to the toxic products of atmospheric reactions (ibid.). In this way, it seems as if public health is being fully protected by the authorities. However, it remains to be seen whether this is the case.

5.2.3 *Protection of Health in Environmental Legislation*

Health protection emerges as a central concern in the Texas air pollution legislation:

> *... pollution is 'the presence in the atmosphere of one or more air contaminants or combinations thereof, in such concentration and of such duration as are or may tend to be injurious to or adversely affect human health or welfare, animal life, vegetation or property, or as to interfere with the normal use and enjoyment of animal life, vegetation or property' (TACB, 1987, p. 2)*
> *... 'to ensure that emissions from new and modified sources do not result in adverse effects on public health or welfare' (ibid., p. 9).*

However, the extent to which health protection can be achieved following the present legislative methods of measuring exposure, reporting excess emission, and accepting the adequacy of the NAAQS to safeguard health is questionable. Five reasons justify this argument.

First, to determine whether each proposed source is in compliance with the intent of the Texas Clean Air Act and to predict the health impact of chemical emissions on the population, the permit authorizing staff use engineering and modelling techniques to estimate emissions and ambient concentrations. For toxicity evaluations, they have to rely increasingly on health effects expertise (TACB, 1987). In technical terms, the process consists of specialist engineers trained in the permit requirements checking the accuracy of the applicant's emissions' estimates as well as assuring that BACT has been incorporated into the design of the facility. Emission rates after control are used as input to the applicant's dispersion modelling. Modelling predicts the worst-case off-property ground-level concentration impacts for the air contaminants involved. The effects evaluation staff then review the concentrations of each of the air contaminants to determine the potential for adverse health or welfare effects or nuisance conditions (ibid., p. 3). The cornerstone of the effects evaluation process is the use of an effects screening level.[5] However, if the screening levels are exceeded, this does not necessarily mean that the project cannot be approved. Instead, a more extensive review is initiated (ibid., p. 5). Health safety therefore may well be overlooked under certain conditions. The thesis does not use the output of this modelling because, although the method may be sensitive to spatial data, it is not sensitive to the actual health consequences suffered by residents exposed to emissions, to topographic and climatic factors which may exacerbate the deleterious effect of toxic emissions, or to additional social factors which may influence the health effects of contaminants (for example, poverty and health care).

Second, the major type of environmental and health problem that the authorities in Houston, and in Texas in general, deal with is odour nuisance (see Chapter 7).[6] To evaluate these situations, the staff review the literature, rather than rely on other methods of measurement, to find the odour thresholds for the substances of interest. If people are exposed to an average concentration of odorous compound equal to the odour threshold concentration, most would notice such an odour. There is, however, an element of professional judgement in assessment as to whether or not an odour nuisance condition will be caused by the emissions from a facility (TACB, 1992d, p. 4). Further, detection of odours may require immediate assessment and this

[5]Screening levels are chosen to protect against adverse health effects, vegetation effects, materials damage including corrosion, and nuisance conditions such as odour. The short-term (30 minutes) health effects screening level is equal to 1/100th of the most applicable occupational exposure limit. For a long-term (annual average) health effects screening level, 1/1,000th of the occupational limit is used. Also, a method for deriving health effects screening has been developed for those cases in which a chemical to be emitted into the air does not have an established occupational exposure limit (TACB, 1992e, p. 4). If there are different screening levels for health, welfare and nuisance conditions, the lowest is used to evaluate the facility's emissions.

[6]The information of vegetation and corrosion effects is much less extensive than for health effects, but it is used when it is available (TACB, 1987).

may at times be impossible. Residents are obviously more capable of assessing this type of odour because they are present at the time of the nuisance and may easily recognize changes in the quality of the air (see sections 7.2 and 7.3).

Third, the system requires the polluter to report its own excess emissions to the Executive Director and to the appropriate local air pollution control agencies as soon as possible after any major upset which causes or may cause an excessive emission that contravenes the intent of the Texas Clean Air Act or the regulations of the Board.[7] Self-reporting, however, is flawed because it depends on the good-will of the owner or operator of a facility. Well-being of the residents may easily be impaired by this procedure because they may not be informed on time to prevent the population from health risks.

Fourth, emissions occurring during major upsets may not be required to meet the allowable emission levels set by the rules and regulations upon proper notification. This is the case if a determination is made by the Executive Director after consultation with appropriate local agencies and with appropriate officials of the subject source that the conditions were unavoidable and that a shut-down was implemented or other corrective actions were taken as soon as practicable. Also, excessive emissions occurring during start-up or shut-down of processes or during periods of maintenance may not be required to meet the allowable emission levels set by the rules and regulations (ibid., p. 16). Clearly, the air may suffer further contamination as a result of such significant concessions in the regulations, which naturally increase the risks of adverse health consequences for the city's inhabitants, and particularly for those who live near the sources of toxic emissions.

Finally, sources emitting air contaminants which cannot be controlled or reduced due to lack of technological knowledge may be exempt from the applicable rules and regulations when so determined and ordered by the TACB (ibid., p. 16);

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[7]The regulations determine that the notification should identify the cause of the upset and the processes and equipment involved, and should include the date and time of the event or up to two weeks after the onset of the upset condition (TACB, 1987).

and information of the health effects of a compound often does not require a tightening of controls on permitted facilities that emit it. The reason for this is that it is thought that BACT requirements have usually led to emissions control that is better than merely adequate to meet a screening level. Also, exceptions from a full permit review are granted to some sources where the residual emissions are thought not to have the potential to cause air pollution (TACB, 1987).

In summary, the government agencies and national standards have been established to protect the health of the population from the environmental impact caused by industrial and other emissions. Nonetheless, the limitations in the modelling methods and flaws in emission regulation preclude the declared commitments to protect health as they appear in the legislation. In addition, whilst measured levels of air pollution may indicate the relative health risk in relation to established health safety limits and to models of exposure (see Chapter 2), the pollutants safety limits imposed by the government have historically oscillated in response to economic and political pressure from industrialists and other forces (see Chapter 5). Therefore, the national standards of air pollutants do not always represent the present health risk of exposure, but rather the pressure to oppose control, and, as a consequence, the 'safety limits' cannot be completely reliable. Also, concentration levels once thought safe have been shown to be harmful to health (e.g. the minimum level of lead in the blood). The established pollutants standards have been conditioned by official acknowledgement of the health risks, and by the will of the government to cut emissions and regulate pollution accordingly. The conclusion to be drawn is that there are intrinsic weaknesses in this way of protecting public health. Indeed, had the regulatory system controlled air pollution in absolute accordance with health standards, there would not have been 279 unhealthy and 37 very unhealthy days during the 10-year period between 1981-1990 in the Houston area (see section 4.4.3). Continuing the examination of the structures that may relate to the state of health in the city, the next section examines the medical care system and the protection of public health.

5.3 Provision of Health Care in Houston

The chapter moves on to examine one additional macro-structure as established in the causal model (see section 3.3). This section locates the Houston health system within US market-oriented medicine and addresses access to health care provision to elicit their possible influences on the state of public health and on that of the surveyed population. A profound contradiction between professional excellence in the medical field in Houston and institutional constraints to access them surfaces from this investigation. Three aspects of institutional health are addressed. First, health achievements in the USA in relation to other major developed nations are outlined. Second, the main characteristics of the US health system and the limitations in providing health care for all are stressed. Thirdly, health care in Houston is considered. Particular stress is placed on access to health care by low-income and the most disadvantaged people. This emphasis is necessary to ascertain how the provision of and access to health care may influence the health status of the population in general, and that of the household sample in particular, and with special relevance here to that of children.

5.3.1 *Public Health in the USA*

> ***The USA health-care system costs more and covers a smaller percentage of the population than systems of any of the other six economic powers (Prof. Michael Swint, in Sorelle, 1990b; with reference to The G-Seven Economic Summit held in Houston in 1990).***

Infant mortality is higher and life expectancy is lower in the USA than in countries with similar, or even lower, GNPs. The portion of the GNP invested in all health expenditures in the USA is only 1.2% (Dougherty, 1988). In comparison, in France and Canada health expenditure is remarkably higher (8.6%), as it is in West Germany, Italy, Japan, and the UK where the amount of the GNP allocated to health care is significantly higher than in the USA (see Table 5.1). Canada, France, West Germany and Japan finance health care through a form of national health insurance. The UK and Italy both maintain publicly provided national health services. Yet, despite the fact that per capita health care expenditure in Italy is two and half times smaller than in the USA, the infant mortality rate is twice as high in the USA (Sorelle, 1990b). Moreover, infant mortality in Germany and in Japan is similar to that in the USA in spite of the fact that the USA expends two or more times as much on per capita health care than the other two countries (see Table 5.1).

Table 5.1 Comparison of health care resources of the major developed nations, 1989

	USA	*Canada*	*France*	*W.G.**	*Italy*	*Japan*	*Great Britain*	*Mean*
% GNP used for health	1.2	8.6	8.6	8.2	6.9	6.8	6.1	8.1
Per capita health care expenditures $	2,051	1,483	1,105	1,093	841	915	758	1,178
Population uninsured (million)	35	0	0	0	0	0	0	
% population eligible	43	100	99	92	100	100	100	91
Infant mortality per 1,000	10.0	7.9	8.3	9.6	5	9.1	8.2	
Physicians income as a multiple of average worker	5.4	3.7	2.4	4.3	N/A	3.9	2.4	3.7

Source: adapted from Health Data File, Organization for Economic Cooperation and Development, 1989, in Sorelle, 1990b.
* West Germany

Primary-care physicians in industrial countries other than the USA are spread throughout the patient population. In Western Europe, Canada, Japan, Australia and New Zealand, 40% to 50% of all clinical physicians are general practitioners. In these countries there is an explicit commitment to universal access to private care in physicians' offices with specialists available on their referral. In the USA, by contrast, only 15% of clinical physicians are general practitioners and there is no guarantee of universal access to them (Dougherty, 1988).

In summary, the roots of the causes of the contradiction between a large health expenditure but poor health achievements in the USA overall, can be traced to the way in which medical care is organized. The state of public health in Houston must be framed within the health achievements of US society as a whole, which are themselves quite poor in comparison with those of other countries in the advanced world.

5.3.2 *Effects of Market-Oriented Medicine*

In general, in the USA, health care, and the health insurance on which it often depends, are distributed in the same way as most goods and services: largely on a pay-as-you-go basis. This marketplace mode of distribution is by its nature bound to work against the interests of those least well off. The usual provider of medical care for most people in the USA is a privately practising physician, whose fees are financed in various ways: by private health insurance, by government-supported public health insurance (Medicare and Medicaid for the eligible poor)[8] or by out-of-pocket payments. Unlike that in comparable nations, US health insurance is largely focused on employer-provided plans. Commercial health insurance is thus linked in general to employment. But employment does not guarantee health insurance because many self-employed, temporary and part-time workers, and those working in small businesses and for low wages, are often uninsured or underinsured.

There is a clear link between health and social class in US society (Dougherty, 1989). This is exacerbated in cases where inability to work because of disability is itself a potent source of poverty. The likelihood of having health insurance varies with ethnicity, income and education. A relative lack of education certainly tends to promote poor understanding of preventive health care as well as less sophistication in drawing appropriate and timely benefits from the health care system. Health statistics reveal that Blacks and other ethnic minorities, the poor, those with low incomes, and the less educated benefit substantially less from the health care system than do other Americans. In the USA, children as a group are less well covered by private health

[8]Medicare, which began to operate in the 1960s, provides affordable health insurance to elderly Americans. Medicaid was devised to provide health care to the poor. The federal government shares the costs under Medicaid, but the individual states set eligibility criteria and administer the programme.

insurance and in addition they, or their parents, pay a higher proportion of medical costs out of pocket than any other age group (Miller *et al.*, 1985).

In the mid 1980s some 35 million Americans were uninsured as a result of the reduced scope and the limited success of national public health insurance. Despite expansions in eligibility criteria, many poor pregnant women and their children do not receive the services they need.[9] A major reason is that the insurance operates as a reimbursement mechanism, rather than as a system care.[10] Other reasons include barriers for patients, barriers for providers and limitations in the services provided under this system (Children's Defence Fund, 1990). It is estimated that millions of poor Americans live in areas with a shortage of physicians. Many of these regions are heavily populated by those groups whose poverty and race do not attract physicians, for in a market-oriented system physicians must establish a private practice and pay off medical school debts and so usually work among those who can afford to pay their fees (Dougherty, 1988). About 50% of practising physicians decline to see Medicaid patients and in many counties within particular states no practitioners at all are available who participate in Medicaid (Dougherty, 1988). In addition, doctors are overwhelming White. The lack of physicians serving the American inner-city Black population is also equally notorious. It remains the case, argues Edgar (1989), that while access to medical services by the poor has improved in the USA since the national public health programmes of the 1960s, those services are inadequate, time-consuming to reach, hospital-based, episodic and disease oriented.

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[9]Little assurance is provided that poor people actually have access to appropriate services. Only about one third of the poor are covered by Medicaid (Miller *et al.*, 1985).

[10]Much like an insurance programme, Medicaid reimburses hospitals, physicians, pharmacies and other health care providers for the medically necessary care they provide to persons covered under the programme.

5.3.3 *Access to Health Care in Houston*

Indigent health care in Houston is a continuing crisis, but it would take little for it to become a major crisis affecting everybody, not just the poor (Dr. Joe Rubio, in Sorelle, 1990a).

The health care sector in Houston is highly developed, containing the world's largest medical centre and one of the most important in the USA. Houston houses the most advanced facilities for research and treatment of cancer (see section 3.2.1). Numerous medical facilities - among them 50 hospitals, 15,651 beds, many clinics and convalescent homes and virtually every medical speciality - are represented (Greater Houston Partnership, 1995/6). In contrast, the medical facilities which care for the uninsured and the poor publicly insured are few and inadequate. There is virtually no access to free health care for the needy. Low income residents are mainly assisted through public health agencies run by the City of Houston Health and Human Services Department authorities, hospitals, and charitable clinics run by volunteers (e.g., Clínica María, see below).

In Houston, the bureaucratic limitations of the public health eligibility process result in more than half of all applications being rejected, mostly for incorrectly filled out forms. Over 75% of urban paediatricians in Texas see less than four Medicaid patients per month and 25% see none at all. In Houston, over 50% of people living below the poverty line do not have any type of health insurance, including national medical insurance. Fewer than half of the children eligible for nutritional support (available to women, infants and children) are actually served by the programme. From 1986 to 1989, the overall Personal Health Services Budget at the City of Houston Health and Human Services Department fell by 15% and the budget for women's and children health fell 80% (Children at Risk Committee, 1990).

For example, for the 750,000 people in Houston MSA eligible for public medical care at the public hospital district, there are only 11 community Health Service Area Clinics (see section 3.5.2 and Appendix A.1) and 1,035 hospital beds.

Moreover, there is no public clinic in the South-West of Houston where a large concentration of immigrants, particularly from Central and South America and many sub- or unemployed are to be found (Urrutia-Rojas, 1988). According to Urrutia-Rojas, who studied the health conditions of the indigent Hispanic population in Houston's South-West, fewer persons have a regular source of health care there compared to the Hispanic population in general and to the US population in total. The only alternative source of health care for most of the population in the poor South-West is a private physician which means that a large proportion of an already low annual income must be spent on health care. Owing to the lack of national health coverage for all, almost 90% of private physicians' visits are paid for in cash. This means that if a person does not have the money, he or she will be unable to receive medical care even when such care is imperative (ibid.). One half of all the thesis' interviews conducted in low-income households are located in the poor South-West which is the control area far from sources of industrial emissions (see section 3.5.2).

Charity clinics fill some of the gaps in the medical care system in Houston. The Clínica María, in the South-West is operated entirely by volunteers. In contrast to the usual rules of eligibility stated by the government, patients do not need to fulfil stringent requirements in order to obtain free health care there (Ada Montalvo, personal communication, August, 1990; see Appendix A.2). The clinic functions in the precincts of a private house whose owners actively promote health care for the poor, in particular, for the *indocumentados*.[11] The staff includes volunteer physicians, medical students and administrators. Medicines, which are donated by pharmaceutical companies, are provided free of charge. Patients obtain primary care and children can be immunized. Nonetheless, the extent of the health care provided is necessarily very limited; despite the fact that the Clínica María is heavily used, it is open only a few hours a day, its premises are small, facilities insufficient, and patients must wait for hours before being seen.

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[11] *Indocumentados* are Spanish-speaking immigrants who have not legalized their residence in the US.

Access to child care in the public sector cannot be assured in Houston because there is no organized system of health service delivery or health records. Many private physicians, public agencies, and charitable/community agencies provide services, but there is little contact between them (Moyer, personal communication, 1992; see Appendix A.2). To cite one example, the schools require proof of immunization, but access to immunization records is readily available only to a small number of children enrolled in welfare programmes such as Well Child Care. Children who have been immunised at community sites have access to their records only if they can recall the exact day and location of the immunization received. Furthermore, there is no tracking and recall system to assure that children receive timely immunizations. Each welfare agency in Houston sets different financial eligibility criteria. The combined effect of these uncoordinated operations is that the patient must invest hours completing repetitious paperwork to obtain public services. Furthermore Houston, public transport is inadequate and often inconvenient. It sometimes involves travelling downtown and changing buses to, in turn, reach the neighbourhood clinic. Moreover, obtaining vaccinations for babies may become extremely difficult if mothers need to travel carrying one or two toddlers (Hardikar, personal communication, 1992; see Appendix A.2).

There is also fragmentation of preventive and treatment services in the Houston Public Health Agencies. A parent has to travel from site to site, usually from one part of town to another, to access health care from one of the three agencies. Moreover, these agencies usually have different eligibility criteria, fee schedules and residency requirements. Also long waiting times are a chronic problem in the public health care system in Houston, a feature which suggests that the capacity to serve is overwhelmed by the demand for care:

> *These children wait for treatment not in the plush surroundings of a private physician's office, but in the crowded waiting area of a public health clinic - the Martin Luther King Health Center in the southeast of Houston. Every weekday, children and adults line up from opening to closing time to see doctors for minor and major aches, X-rays, and various other*

needs. The MLK centre and the other county and city health clinics are the primary health care providers for the poor. But physicians say the badly needed medical care is not always easily accessible (Seay, 1990).

In summary, it has been shown that access to health care in Houston is very limited, despite world recognition of its excellence in medical facilities. The delivery of health care has been hampered by profit-making medicine and a bureaucratic process of eligibility to obtain national supported health insurance. On the other hand, air pollution regulations have been shown to be flexible to the point where these may displace health concerns to accommodate pro-economic growth activities. To appreciate the possible implications of health and environmental macro-structural institutions, the next section will analyze public health in Houston. In this way, the chapter will attempt to relate institutional structures and environmental events.

5.4 The State of Public Health in Houston

In view of serious and prolonged contamination of the air, the present section addresses the issue of the extent and characteristics of ill-health in Houston. This enquiry follows the line of thought developed in the thesis and the causal model established in Chapter 3 whereby ill-health is the likely outcome of a series of macro- and micro-structural factors and inherent physical characteristics. Examination of public health in Houston was carried out by studying a number of relevant indicators on mortality, disease mortality and morbidity. In particular, cancer risks and cancer death from the respiratory organs were looked into in detail because of both notoriously high rates in Houston, and possible links of the disease to environmental conditions. Unless stated otherwise, the documentary information, particularly in the first part of the present section was taken from the annual reports by the City of Houston Health and Human Services Department. (1984-1991) (see Appendix C.3.2). Although official health statistics are valuable because they describe the overall health trends in Houston, these are classified only by demographic characteristics, i.e., age, sex and ethnicity and do not include socio-economic and spatial variables of the deceased or diseased. The analysis carried out for these data is descriptive because the groups used for analyzing the events of ill-health and mortality are not causally related. Quantitative assessment was very useful for determining the degree of the problem, comparing it to that in other cities, and above all for signalling the need for additional research.

5.4.1 *Rates and Causes of Mortality and Morbidity*

General mortality in Houston for each year examined since 1984 was higher than the corresponding US mortality rates.[12] Whilst US age-adjusted death rates have decreased regularly, in Houston mortality trends have remained consistently high (see Table 5.2).

Table 5.2 Age-adjusted overall death rates* compared: Houston and USA, 1984-1990

Year	*Houston*	*USA*
1984	626.3	545.9
1985	609.3	546.1
1986	597.8	542.7
1987	598.0	535.5
1988	622.7	536.3
1989	612.0	523.0
1990	695.1	N/A

Source adapted and calculated from City of Houston Health and Human Services Department 1984-1988, I, p. 3-5 and City of Houston Health and Human Services Department, 1989-1990, p. 76.
*Deaths per 100,000 population

The infant mortality rate, which includes infants from 0 to 1 year of age, is one of the best indicators of quality of life because babies in this group are particularly sensitive to social, economic, and medical care changes (Boone, 1989). Between 1978 and 1985, Houston was among the 20 largest US cities with the highest infant mortality rate (e.g., in 1985 Washington, DC had the highest infant mortality rate in the USA, 20.8 per 1,000 live births; Detroit, 19.9; Philadelphia, 17.4; New York, 12.8; Dallas, 11.1; Houston, 11.2; Phoenix, 9.9; San Diego, 9.3) (U.S. National

[12]Age-adjusted death rates, as opposed to crude rates, control for the effects of different age structures (see Appendix C.2.2).

Center for Health Statistics, 1987, cited in Boone, 1989). Between 1988 and 1990, infant mortality rates for Houston were also significantly higher than those for Texas and the USA (see Table 5.3). In 1988, Houston infant deaths accounted for 1.1% of all infant deaths in the entire USA.

Table 5.3 Infant mortality rates* compared: Houston, Texas and USA, 1988-1990

Year	*Houston*	*Texas*	*USA*
1988	11.4	9.1	9.9
1989	11.1	8.0	10.0
1990	9.3	N/A	N/A

Source: adapted from City of Houston Health and Human Services Department I, 1984-1988, Table 2.1 and City of Houston Health and Human Services Department, 1989-1990.
*Deaths per 100,000 population

Infant mortality is even higher in Houston's inner city, a problem characteristic of many industrial cities. In areas of Chicago, Detroit, New York City, and Houston, the infant mortality rates approach those found in Third World countries (Sorelle, 1990d). In Houston's inner city, the infant mortality rate in 1989 was a stunning 20.0 per 1,000 live births. This was worse than the rates in 25 other nations, including Cuba and Bulgaria (*Houston Post*, 1990a). Based on their high number of infant deaths, Jamaica (18 for every 1,000 live births) and Chile (19) received emergency funds from UNICEF in 1989. In light of this, if, for example, the Fifth Ward neighbourhood in Houston inner-city downtown were a country of the Third World, it would, paradoxically, qualify for aid from UNICEF (*Houston Post*, 1990b).

Infant mortality rates vary greatly according to ethnic group (they may be correlated to income). For both infant mortality and life expectancy the statistics are far more favourable for Whites than Blacks. In 1990, as in previous years, Blacks had the highest infant mortality rate in Houston at 16.9%; the rate for Whites was only 5.8%, for Hispanics 6.7% and others 6.7% (Rich, 1990).[13] While Whites born in 1989 had a life expectancy of 75.9 years, the life expectancy of Blacks was just 69.7 years (see Figure 5.1).

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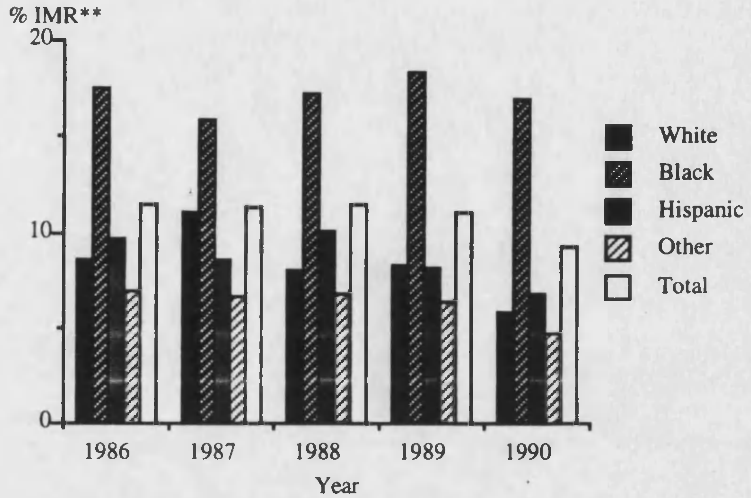
[13]Mexican-American infant mortality, however, was found to be unexpectedly low (*Houston Chronicle*, 1990a).

Figure 5.1 Infant mortality rates* by ethnicity, Houston, 1986-1990



Source: data from City of Houston Health and Human Services Department, I, 1984-1988, p. 2-5 and from City of Houston Health and Human Services Department, I, 1989-1990.
*Infant Deaths per 1,000 live births; ** Infant Mortality Rate

Moreover childhood mortality is very high in Houston: in 1989 there were 35.1 deaths per 100,000 population aged 1-14 years; and in 1990 there were 49.5. The 1988 rate for maternal deaths (8.2 per 100,000 live births) was slightly higher than the USA rate (7 per 100,000 live births).[14] Although no single cause for the deaths has been pinpointed, maternal mortality has been said to correspond to Houston's high infant mortality rate and that the maternal mortality rates for both groups are directly related to deficient prenatal care (Sorelle, 1990c). Public hospitals in Houston usually have higher rates of maternal mortality than private hospitals.

Disease Mortality

The five leading causes of death in Houston listed in descending order during 1990 were heart disease,[15] malignant neoplasm (cancer),[16] cerebrovascular diseases,

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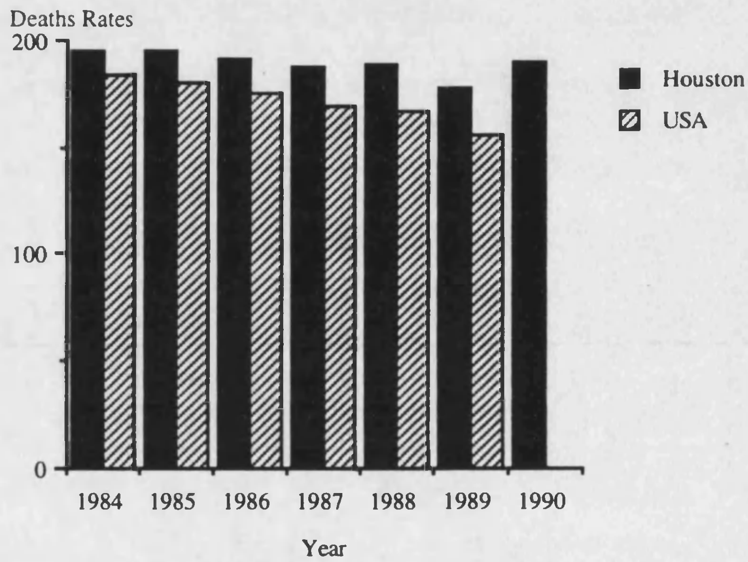
[14]In 1989 the rate was 15.8 per 100,000 live births; in 1990 it was 10.0. In 1989, the number of deaths increased dramatically because thirteen women died in public county hospitals in one year while three to four women died each year between 1981 and 1986. In 1989, the death rate at the L.B. Johnson county hospital was 82 deaths per 100,000 live births, compared with 21 to 22 in the previous years (Sorelle, 1990c).

[15]The age-adjusted death rate was 188.8 per 100,000 population.

[16]For the incidence of cancer in the state of Texas see the joint publication by the Texas Cancer Council, the Texas Department of Health, the University of Texas M.D. Anderson Cancer Center & Other Institutions, 1991 (see also Appendix C.3).

accidents and adverse effects, and homicide and legal intervention.[17] Together they accounted for 66.1% of all Houston deaths. Comparative data on mortality disease have shown evidentially that ill-health may well be a problem in Houston. Indeed, heart disease rates for Houston for 1986-1990 were consistently higher than those of the US age-adjusted rates for the same period (see Figure 5.2).

Figure 5.2 Comparing age-adjusted heart disease death rates,* USA and Houston, 1986-1990**

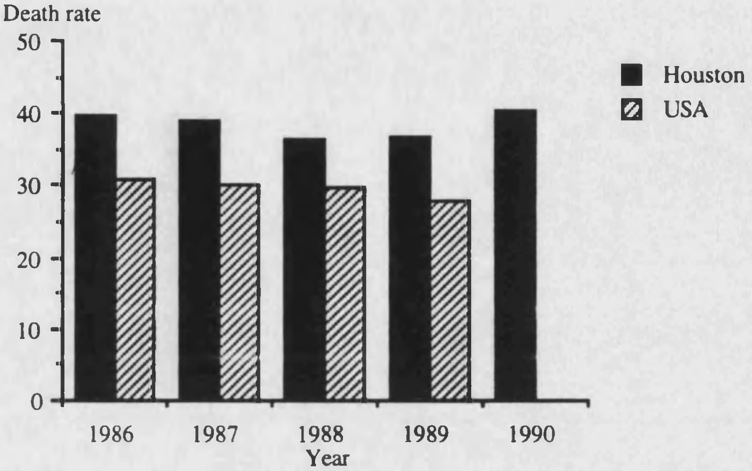


Source: adapted from City of Houston Health and Human Services Department, I, 1984-1988; City of Houston Health and Human Services Department, 1989-1990.
*Deaths per 100,000 population;** Death rate not available for USA 1990

Also the 1986-1990 age-adjusted death rates for cerebrovascular disease in Houston were much higher than the corresponding US rates although both showed a modest but steady decline during the four-year period (see Figure 5.3).

[17]The 1990 rates use the 1990 census. The 1989 and 1990 rates which use population data in the denominator should not be compared.

Figure 5.3 Comparison of age-adjusted cerebrovascular disease death rates,* USA and Houston, 1986-1990



Source: data from City of Houston Health and Human Services Department, I, 1984-1988, City of Houston Health and Human Services Department, 1989-1990.
*Deaths per 100,000 population

Infectious Diseases in Houston

The incidence of communicable diseases, such as tuberculosis, measles, and sexually transmitted diseases,[18] is much higher in Houston than the national average and the rate of death due to such diseases is three times the national average (Children at Risk Committee, 1990). Most of these infections are actually preventable or easily curable with present treatment. However, the wait for appointments in the city's tuberculosis clinics during the 1989-1990 school year was up to 90 days. Apart from lack of availability of and accessibility to services which prevents appropriate care from reaching those who need it, there is also a lack of Spanish-speaking nurses in the city's tuberculosis clinics. This happens in spite of the fact that 50% of the cases are in patients of Hispanic origin.

[18]Altogether, there are 52 infectious Reportable Diseases and 4 Reportable Occupational Diseases. Among them AIDS, syphilis and gonorrhea show high incidence in Houston. According to the Center for Disease Control (CDC), Houston represented the fifth largest AIDS case load of all metropolitan areas nation-wide. The largest case loads are in the metropolitan areas of New York City, Los Angeles, San Francisco and Miami. These are followed in size by Houston, Washington DC, Chicago and Newark (City of Houston Health and Human Services Department, 1991).

Incidence of tuberculosis in Houston has traditionally been remarkably higher than national rates.[19] During the 1986-1990 period, tuberculosis rates in Houston doubled compared to the corresponding US incidence (e.g., in 1990, the rate was 20.4 in Houston and 10.4 incidence per 100,000 population in the USA; in 1986, the respective rates were 18.0 and 9.4). Children under 15 years of age represented 6.4% and 7.6% of the tuberculosis cases reported during 1989 and 1990 respectively (City of Houston Health and Human Services Department I, 1984-1988, 1989-1990).[20]

Measles is a highly communicable infectious disease caused by the measles virus. Since the vaccine was introduced in the USA in 1963, the reported incidence of measles has decreased by 99%. Nonetheless, the number of measles cases in the USA began to rise precipitously in 1989. In 1990 there were almost 28,000 cases and 97 deaths. Houston, for example, experienced an extensive measles outbreak from early October 1988 to late September 1989. The virus has persisted in un-immunized children living in sizeable pockets of urban poverty (Fenner and White, 1976). Measles is a preventable disease hence the upsurge of cases in the USA has been attributed to the high price of the vaccine. Many community health centres could not obtain sufficient supplies to meet the needs of all their patients because of high prices per dose (Knight, 1991). In fact, measles outbreaks in Houston involved primarily unvaccinated Black and Hispanic pre-school children. Of the overall outbreak in Houston, 30% or 526 cases were preventable.[21]

In summary, Houston's remarkable morbidity levels, high rates of infant, childhood and maternal mortality, and cancer mortality are all the more remarkable if

[19]Measures of morbidity are aggregated for Houston and Harris County, both within Houston MSA (see section 4.2.1).

[20]High immigration, particularly from the Mexican border, has contributed to maintain the very high incidence of tuberculosis. Moreover, there is a clear ethnic gradient with Blacks and Hispanics showing the highest rates (in 1990 the rates were 45.5% and 43.2% respectively; 6.8% White, and 4.5% Other).

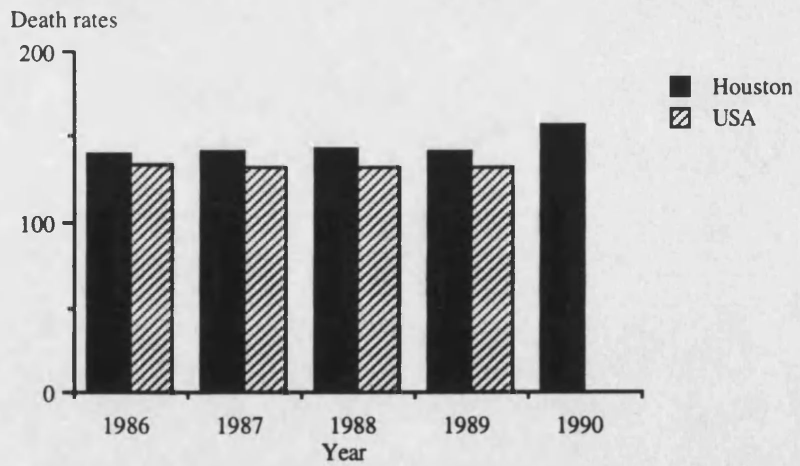
[21]A preventable case was one in which the individual was at least 16 months; was born after 1956; lacked adequate evidence of immunity, had no medical contra-indication to vaccine; and had no religious exemption under Texas law. A non-preventable case was one in which the individual was less than 16 months; was born before 1957; had adequate evidence of immunity; had a medical contra-indication to vaccine; and had a religious exemption under Texas law (City of Houston Health and Human Services Department, I, 1984-1988, p. 8-3).

we consider that in 1988 the city ranked among the 10 wealthiest areas in the USA in terms of personal income (*Houston Chronicle*, 1990b). A further contradiction was that while infant mortality rates in Houston's inner city were comparable to those in Third World countries, 10 citizens of Houston appeared on the annual list of the 400 richest Americans (Boisseau, 1990).

5.4.2 *Respiratory Cancer Mortality*

Malignant neoplasm, commonly known as cancer, is the second leading cause of death in Houston (see section 5.4.1). From 1984 to 1989 the Houston cancer age-adjusted mortality rates were significantly higher than the corresponding USA rates; the 1990 rate is remarkably high (this should not be compared to previous years' rates though, see footnote in section 5.4.1) (see Figure 5.4). The annual childhood cancer mortality rate has been stable between 1984-1988 at 3.0 per 100,000 population. However, that for 1989 and 1990 is very high (4.0 and 5.4 per 100,000 population respectively).

Figure 5.4 Age-adjusted cancer death rates,* Houston and USA, 1986-1990



Source: adapted from City of Houston Health and Human Services Department I, 1984-1988, p. 5-3; and City of Houston Health and Human Services Department, 1989-1990.
* Incidence per 100,000 population

Respiratory cancer is the leading sub-category of the disease to cause death in Houston (it represents more than 30% of all cancer deaths; it is followed by mortality from cancers of the digestive organs and peritoneum, of all other and unspecified sites, of the genital organs, of the breast, and of the lymphatic and hematopoietic tissues other than leukaemia cancers).

Respiratory cancer death rates in Houston are remarkably higher than the US national rates (see Table 5.4). Compared to other causes of cancer-associated deaths, the prevalence of respiratory cancer is higher among men (although it is also very high among women, see Figures 5.5 and 5.6).

Table 5.4 Age-adjusted respiratory cancer death rates,* USA and Houston, 1984-1988

Year of death	*Houston*	*USA*
1984	44.9	38.4
1985	40.9	38.8
1986	40.5	38.3
1987	44.3	39.3
1988	44.9	40.6
1989	45.5	40.3
1990	49.8	N/A

Source: adapted from City of Houston Health and Human Services Department I, 1984-1988, p. 5-3; and City of Houston Health and Human Services Department, 1989-1990, p. 140.
* Incidence per 100.000 population

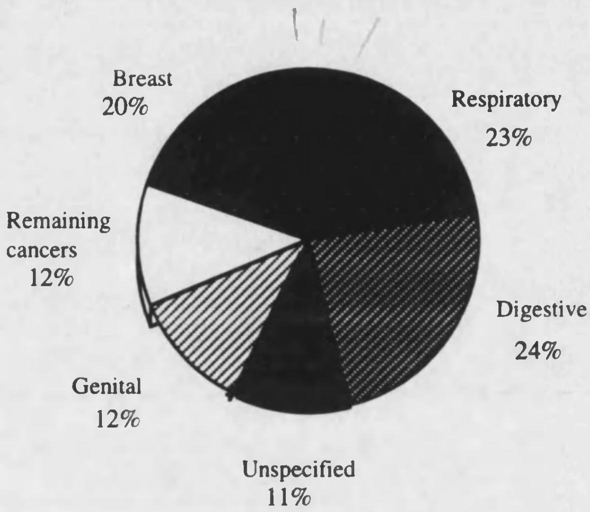
General cancer death has been attributed mainly to ethnicity, but differences in respiratory death cancer rates in particular have been attributed to gender. In fact, neither explanation on its own seems plausible in face of their narrowness. They ignore a wide range of social and other conditions of the deceased, including exposure to environmental pollution. For example, Figures 5.5 and 5.6 show that, although respiratory cancer occurs more often among males than females, it is a disease that significantly afflicts both populations.

The role of environmental industrial pollution in cancer mortality in Houston was substantially addressed by MacDonald (1976) whose study is apparently the only one to have linked air pollution and mortality in Houston. She analyzed all death certificates in Houston from all causes since 1940 to 1975 and re-coded them according to the International Classification of Diseases 1955 rubrics.[22] A significant

[22]Death certificates were classified by age-adjusted mortality rates from heart disease, cancer, stroke as well as from all other causes, total respiratory disease and from malignant respiratory disease.

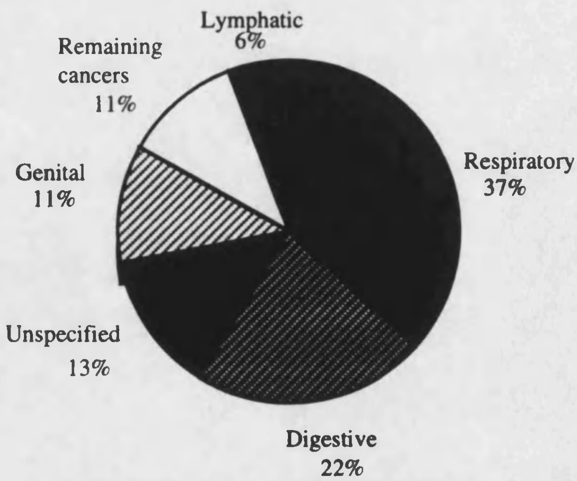
relationship was found between industrial ambient pollution and the pattern of cancer mortality, accounting for demographic factors, addresses and exposure to atmospheric pollutants in 15 regions within the city grouped around air pollution sample collection stations. These results were very important because cancer mortality was convincingly correlated to local variations in air pollution.

Figure 5.5 Distribution of the five leading causes of female cancer mortality, Houston, 1990



Source: adapted from City of Houston Health and Human Services Department I, 1989-1990 p. 137.

Figure 5.6 Distribution of the five leading causes of male cancer mortality, Houston, 1990



Source: adapted from City of Houston Health and Human Services Department I, 1989-1990 p. 137.

The addition of relevant additional indicators in present recording of public health, such as the address of the deceased in relation to sources of pollution, could definitely help to ascertain more accurately the causes of death in Houston. This seems the most appropriate method taking into consideration that air pollution in Houston may reach dangerous levels and that the usual level of pollutants is moderate to high (see section 4.4). Hence, it might well be that high respiratory cancer death rates are exacerbated by high air pollution in the city. Other diseases particularly those of respiratory origin, have been related to excess air pollution (see section 2.4.1).

5.4.3 *Air Pollution and Increased Cancer Risk*

Estimates of cancer risks from outdoor exposure to airborne pollutants have been expressed as cancer risk in excess lifetime individual cancer risks and nation-wide annual cancer cases (US EPA, 1990b). The maximum lifetime individual risks estimate is $1x10^{-4}$ (1 chance in 10,000 of contracting cancer). Maximum lifetime individual risk levels exceeding $1x10^{-4}$ were reported for multi-pollutant exposures from such sources as those found in close proximity to major chemical factories, waste oil incinerators, hazardous waste incinerators, municipal landfill sites, and publicly owned treatment works (all of which abound in Houston). Nation-wide annual cancer incidence, based on 90 pollutants and over 60 source categories examined, is estimated to be between 1,700 and 2,700 cancer cases per year. This is equivalent to between 7.2 and 11.3 cancer cases per year per million population. Using a total 1986 US population of 240 million, it is estimated that approximately, 500 to 900 more cancer cases will occur per year (ibid., pp. 4-1, 4-2).

There are thousands of airborne chemicals that are potentially carcinogenic, but have neither adequate exposure nor health effects data (more than 2,800 compounds have been identified as existing in the atmosphere; ibid., pp. 2-37). For example, the highly carcinogenic properties of some air pollutants are well known. It is clear that particles derived from diesel exhaust have a greater effect on biological processes, including lung tumour development, than those from petrol exhaust (Department of Health, 1995). Moreover, studies in the UK have revealed that potential damage (synergism) has been seen following exposure of animals to some combinations of pollutants (ibid., 1995).

Of the 90 pollutants evaluated in the EPA cancer risks study, 12 account for over 90% of total annual cancer incidence (US EPA, 1990b, p. ES-3). However, reliable quantitative emission estimates remain unavailable for many potentially important source categories. The lack of data for these pollutants and source categories could result in a significant underestimate of risk. Information is also missing on the risks associated with pollutants photochemically formed in the atmosphere, that is, secondary formation. There is evidence that mutagenicity (the ability to cause a permanent change in the structure of DNA) of mixtures of some pollutants increases greatly as they undergo transformation, i.e., mixing in the atmosphere. However, insufficient data are available to derive cancer risk estimates for these.

Both mobile and stationary sources of emission have been found to contribute significantly to the total nation-wide annual incidence of cancer. Considering both direct emissions to the atmosphere and secondary formation, mobile sources had been estimated to be responsible for approximately 58% and stationary sources approximately 42% of total annual cancer incidence. The relative contributions of point and area sources to total area-wide lifetime individual risks are consistent with the character of a study of six American geographic locales. In five less-industrialized cities, the chemical 1,3-butadiene, a recognized major carcinogenic, was estimated to contribute between 6% and 24% of the total cancer incidence, all attributable to motor vehicles. However, in the sixth, a heavily industrialized city, over 48% of the total cancer incidence was attributed to 1,3-butadiene. Of the 1,3-butadiene related cancer incidence in this city, over 80% was attributed to chemical manufacturing plants and less than 20% to motor vehicles (ibid., pp. ES-1 and 4-10). In summary, the range of estimated excess cancer cases per year is likely to be attributed to the following factors: (1) diesel particle and products of incomplete combustion; (2) dioxin emissions from treatment, industry, storage and disposal facilities for hazardous waste; (3) the cancer-causing portion of gasoline vapours; and (4) one fraction of total chromium.

Bearing in mind that due to the effect of airborne pollutants, estimated excess lifetime individual cancer risks and estimated cancer incidence are very high in the USA; that in Houston, actual mortality cancer rates are higher than national average; and that levels of air pollution in the city may reach high levels (see section 4.3), it is reasonable to hypothesize that there may be a link between the state of the environment and the state of health of the population in Houston. More epidemiological studies of the type carried out by MacDonald (1976) would be helpful in order to describe the relation between air pollution and cancer mortality in industrial cities.

5.6 Conclusion

By addressing the environmental and health institutions that deal with the problems that economic growth has created in Houston, Chapter 5 contributes to a deeper understanding of the role of macro-structures on the coincidence of events which emerged from the enquiry in Chapter 4, i.e., huge industrial growth, high levels of air pollution, and spatial patterns of risk. Social and political, as well as ecological and health analyses, have been conducted on a theme which is seemingly only physical. In this way the thesis poses a challenge to traditional methods which separate the social and the natural and de-politicize concrete environmental problems.

The chapter has shown that government attempts to assert power in areas previously controlled solely by the corporations met their opposition, particularly over one of the most volatile of the issues, pollution control. Changes in the legislation produced national standards for a number of pollutants and allowed for subsequent federal intervention in state pollution affairs. Nonetheless, neither state nor federal efforts to control air pollution in the Houston area were meant to interfere with strong trends of economic growth. The outcome has been that the environment was weakly protected by legislative means and, as a result, the population has been exposed to sporadic but severe environmental pollution and hazards, more so in the Ship Channel area what reflects a general spatial form of risk. Notwithstanding that Houston stands out as an economically prosperous city in the USA, and that the city prides itself on in its medical facilities and specialized health services, the chapter has demonstrated that provision of health care for all is severely constrained by major structural obstacles rooted in the market-orientation of the medical sector. Analysis of public health indicators has shown relatively poor achievement in Houston, which is even more surprising if one bears in mind that US health achievements lag considerably behind those of the other six major world economies. In addition, there is an indication that significantly high levels of mortality and, particularly, of respiratory cancer in the Houston area were possibly related to the adverse effects of exposure to industrial emissions.

The contextual analysis of the thesis has been completed in Chapters 4 and 5. It consists of three substantial bodies of knowledge. First, a thorough examination of documentary information on the quality of the air and on the state of public health in Houston; second, solid analysis of the historical process of capitalist growth and environmental degradation in the Houston region; and third, a comprehensive study of governmental control of both industrial toxic emissions and institutional health care. The integration of residential areas, nearby industrial plants, and ubiquitous pollution substantially shows one concrete manifestation of the process of capital accumulation. It creates differentiated spatial configurations within the city as seen in relation to the Ship Channel area. The findings of the APCHS household survey will be analyzed within this political-economy and biological framework of spatial differentiation. However, because the view that space makes a difference to the events themselves is integral to the conceptual approach of this thesis (see section 2.6), the active role of space in determining social and health state will be thoroughly analyzed in the next chapters. We move on now to expand the analysis of air pollution and economic growth in Houston by focusing on the examination of localized and carefully selected events in their unequal social and spatial patterns, especially within the unique configuration of the Ship Channel area.

CHAPTER SIX

THE HOUSEHOLD AND CHILD ILL-HEALTH: IMPACT OF SOCIAL AND LOCATIONAL FACTORS

6.1 Introduction

Chapter 5 has established that, despite the City of Houston and the State of Texas authorities' environmental regulation of industrial emissions and new plants, the legislation has clearly accommodated with the same economic trends which, since the beginning of the twentieth century, have caused severe environmental degradation and, apparently, contributed to increase the levels of cancer mortality (see section 5.4.3). The fundamental information on air pollution and on the state of public health in Houston has been discussed in previous chapters. The complex relation between historical processes, social structures and ecological mechanisms has been detected in spatialized concentration of manufacturing and high risk of environmental accidents in the Ship Channel area. However, what measures and structures cannot show is whether and how residents experience daily this conjuncture. The household survey was essentially a means to produce this empirical information which was causally relevant. The objective of the household survey was, first, to reveal the extent and type of child ill-health; second, to assess the most influential household circumstances which had contributed to the current state of child health; and, third, to look at localized interaction of processes. In this thesis, child health and air pollution are the parameters of change related to the contradictions of economic growth (see Chapter 2). The purpose of Chapter 6 is to analyze the interaction of processes in terms of household circumstances, the health of children and geographical location. This analysis is crucial to determine the political and economic character of the relationship between environment and society and to identify the main micro and macro structural causal factors.

The procedures and analyses in Chapters 6 and 7 are conceptualized through a critical realist approach as developed in Chapter 3 in the following ways. First, child ill-health in the households is addressed as a complex relationship where physical mechanisms and socio-economic micro structures interact and have powers of causation. Second, contingent relations between social and locational household variations are thoroughly examined because of their possible effect on health. Third, the investigation was carried out in such a way that extensive and intensive research complemented each other and rendered crucial information for both quantitative and comparative analysis (see section 3.4.3).

The term *child ill-health* is used here to indicate those households which reported at least one child suffering from at least one recurrent health disorder (see section 3.2.3). Notwithstanding that most reported symptoms are respiratory, it was decided to employ the more general term ill-health to avoid narrowing the effect of air pollution to only one type of illness. Rise in air pollution may also trigger, for example, stomach problems or headache (see section 7.3.3). The chapter draws on the APCHS (1990) (see section 3.4.3) of low- and high-income households located in two contrasting geographical areas, in the Ship Channel, situated near the petrochemical and other industrial facilities and being highly air polluted, and in the South-West, the control area far from the industrial sources of toxic emissions. The chapter does not try only to correlate variables, but to use comparative analysis in order to search for indications of causal processes to narrow down the list of possible factors to those which might have had relevant powers and liabilities. Identifiable households and geographical areas are thus disaggregated and child health variation is compared in relation to the household context. Bi- and multivariate statistical analyses, with one dependent variable, have been used to measure and explain common and distinguishing properties of variable relations. The P values that accompany some associations highlight the significance of the association and by no means are intended to infer causality.

6.2 Description of Sample Households and Child Health

The purpose of this section is to characterize the sample households and to describe the extent and type of child ill-health uncovered by the survey. Indeed, assuming that the state of health of the household members reflects micro-structural features, as established in our causal model (see section 3.2.2), knowledge of the composition and socio-economic status of the household is essential (for a definition of 'household', see section 3.5.2).

Most indicators rated very similarly in the Ship Channel and the South-West residential areas. The average number of children per household was identical in the two study areas. Slight differences were found, however, when the same variable was observed in low- and high-income households and their distribution compared. For example, lowest and highest income households were found in the South-West. Income differentials can be correlated with the fact that there were 28% more households in the South-West where the mother was employed in the highest job category. Yet, a large number of households in the Ship Channel reported mothers employed in the second highest category, the intermediate. As to the domestic category, a fairly similar number of households was found in the two surveyed areas. In addition to the APCHS household survey, the study by Urrutia-Rojas (1988; see section 5.3.3) shows the inferior living conditions of low-income population in poverty pockets in the south-west, that social conditions there are particularly precarious, and that unemployment is very high, 26.6% (this compares to 8.9% in the state of Texas and 7.0% in the USA). For those in work, the median individual income was $600 per working month, the lowest pay being $120 and the highest $900, with only one person reported in the latter category (ibid., p. 36). The APCHS found that shared housing facilities in the poor South-West study area were deteriorated, that vegetation growing on common/public grounds was scarce, stair-cases and landings were normally dirty, and sections of the buildings commonly showed signs of vandalism. On the other hand, the high-income area in the South-

West was very prosperous from the point of view of housing, commercial centres, road networks, medical facilities, and so on (see Table 6.1).

Table 6.1 Demographic and socio-economic composition of surveyed households, Houston, 1990

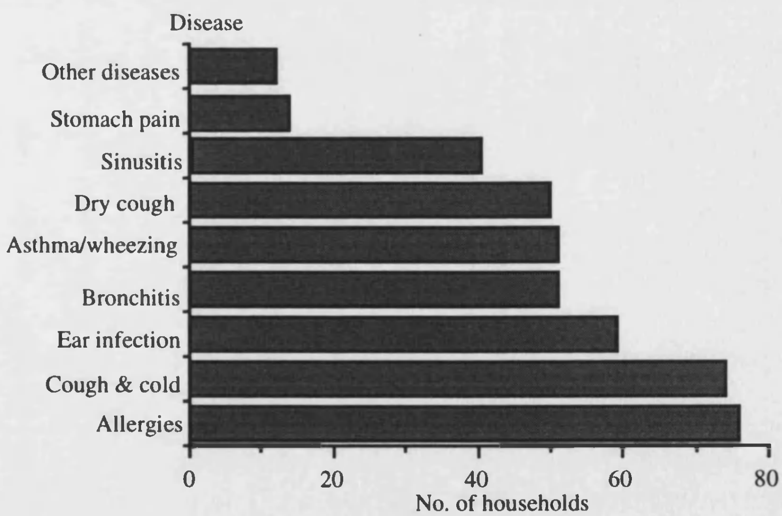
Indicators per household	*Ship Channel polluted area*	Low income households	High income households	*South-West less polluted area*	Low income households	High income households
Family size	5 members	4.9 (SD=1.8)	4.5 (SD=1.2)	5 members	5.7 (SD=2.2)	3.9 (SD=.84)
Average no. children	3 children	2.7 (SD=1.5)	2.3 (SD=1.0)	2 children	2.8 (SD=1.7)	1.9 (SD=.7)
No. of children per household	31 H/hlds	14 H/hlds	16 H/hlds	44 H/hlds	20 H/hlds	24 H/hlds
1	53	26	28	53	18	35
2	44	21	23	27	13	14
3	22	14	8	26	24	2
4***						
Household monthly income	$2,250	$1,300	$3,200	$2,270	$1,140	$3,400
Av. Income per member	$450	$265	$711	$454	$200	$872
*Bedroom occupancy**	3/5*			3/5*		
No. bedrooms	3	2.2 (SD=.80)	2.9 (SD=.71)	3	1.8 (SD=.78)	3.09 (SD=.80)
Dampness	19%	24%	13%	18%	21%	15%
Amenities						
AC**	42%	31%	52%	93%	87%	99%
Conditioner	30%	29%	49%	10%	13%	7%
Heating	31%	31%	32%	30%	4%	55%
Telephone	92%	83%	100%	80%	60%	100%
Occupational class (h/hlds)						
Professional	19	2	17	37	0	37
Intermediate	21	4	17	15	3	12
Semi-skilled	43	22	21	37	29	8
Unskilled	17	14	3	4	3	1
Domestic	47	30	17	54	39	15
Parental Structure						
One parent	25%	35%	15%	17%	24%	9%
Two parents	75%	65%	85%	83%	76%	91%

* Number of bedrooms per number of members in the household; SD: standard deviation
** Central air conditioning
***Four or more children per household

Perhaps one of the most important issues to emerge from the questionnaire was the overall high number of households with reported child ill-health. Indeed, 68%

of all surveyed households (n=300) reported at least one child with recurrent illness. Examination of the specific reported health problems that afflicted children offered a further insight, this time on the particular type, and perhaps severity, of widespread ill-health in Houston. An overwhelming proportion of the reported health disorders was of respiratory origin (94%) (see Figure 6.1). In terms of disease, coughs and colds, allergies, ear infections and bronchitis were often reported. A considerable percentage of households reported children with asthma/wheezing. The prevalence of respiratory disease in particular suggested that either poverty or wider environmental factors, or perhaps both might have contributed to this particular pattern (for poverty see for example, Jolly, 1990; Blaxter, 1990, 1983; Black *et al.*, 1982; Dawson *et al.*, 1969; for environmental factors see, e.g., Ransom and Pope, 1992; Goren *et al.*, 1990; Pope 1991; 1989; Ostro, 1990; Dockery *et al.*, 1977; for a combination, see e.g., Sobral, 1989; Haan *et al*, 1987; see section 2.6)

Figure 6.1 Prevalence of reported disease* in the surveyed households, n=300, Houston, 1990



*The total number of reported disease was 453.

Statistical analysis of aggregated household data, without specifications of location and income, is essential because it reflects, plainly and efficiently, the magnitude and characteristics of the problem. As discussed in Chapter 3, availability of government information on child health across the city was hardly existant and not adequate. The findings of the extensive stage of the research (i.e., without qualifying the households by location and socio-economic circumstances) are the starting point for a deeper investigation of the incidence of child ill-health found in the randomized clusters (see section 3.5.2). Participants in the household survey were identified by causal groups as well, i.e., the geographical location of the household, in the Ship Channel and the South-West, and low and high-income conditions. Therefore, comparative analysis could be carried out.

The results of the survey on the socio-economic and demographic composition of the sample households in the two study areas reinforce the particular selection of comparative randomized clusters. Since the composition of households in the Ship Channel and the South-West is very similar, one rational conclusion would be that given that children were brought up under similar household circumstances in the polluted and the less-polluted areas, the state of child health would be similar. The rest of the chapter deals with this enquiry.

6.3 Effects of Social Inequality

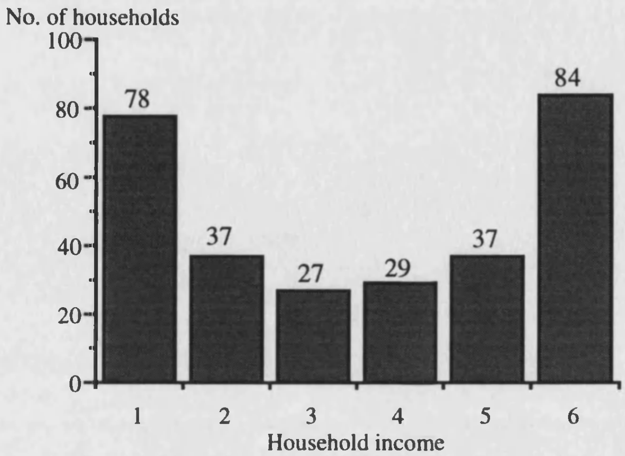
Since the purpose of the survey was to reveal causally relevant associations, comparative analysis of the 300 surveyed households was carried out. The purpose of this section is to ascertain whether and which socio-economic conditions in the household promote child ill-health. It is shown that a great degree of context-dependence characterizes the relationship between air pollution and child health and that social and spatial contingencies are influential on whether and how physical mechanisms result in ill-health.

As has been established in section 2.5.4, if we use only the indicator social class, in the sense of employment status, without further specifications, the analysis will suffer many limitations because social class as such can hardly determine outcomes as it acts only as a sign for social and economic differences among groups of people. Under US market-oriented medicine, health care must be bought like any other commodity; examples include the provision of health care, medical insurance, decent housing, location in a good neighbourhood, and so on (see section 5.3.2). Individual income, therefore, plays an important role in relation to the state of health. Although the level of household income has rarely been included in clinical data as a predictor of child ill-health, there is strong evidence that poor people suffer more ill-health (e.g., Jolly, 1990; Hicks *et al.,* 1989; Dougherty, 1988; Miller *et al,*, 1985) (see section 2.5.1). Hence, this section examines the relationship between three dimensions of the household and the incidence of child ill-health, and assesses whether these variations are modified by geographical location. First, whether the incidence of child ill-health correlates with social inequality (i.e., household income, which is the most relevant indicator of social class), medical expenses and dampness. Second, whether the mother's occupational class affects the incidence of child ill-health. Third, whether the number of resident children and parental structure are detrimental to child health. These circumstances are compared in low- and high-income households interviewed in the polluted Ship Channel and less polluted South-West areas. For the purpose of comparative analysis, the sample population was thus qualified into two groups, the low- and the high-income households but the actual income categories are used as well, e.g. for regression analysis. The analytical approach adopted here moves from aggregated to comparative analysis. That is, the analysis has been expanded from simple frequencies and descriptive correlation to causal associations. In this way, through comparative study, variation and complexity of real child ill-health could be 'controlled' and, therefore, examined.

6.3.1 *Household Income and the Incidence of Ill-Health*

The monthly income of the surveyed households ranged between less than $1,000 to more than $3,000 (see Figure 6.2) with the same number of households in low- and in high-income categories.

Figure 6.2 Household* average income of the sample population, Houston, 1990**

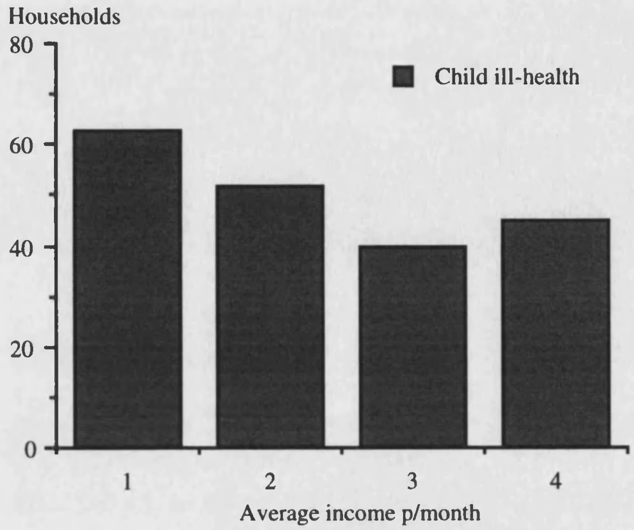


*n= 242 households
**Average monthly income: 1, Less than $1,000; 2, between $1,000 and $1,500; 3, between $1,500 and $2,000; 4, between $2,000 and $2,500; 5, between $2,500 and $3,000; and 6, more than $3,000

More child ill-health was reported among low- (75%; n=150) than high-income households (61%; n=150). This finding corroborates the effects of social inequality on child ill-health as described in the literature (see section 2.5). Nonetheless, the gap between the incidence of child ill-health in low- and high-income households in the Houston sample population was small (14%) despite the wide range of average monthly income (see Table 6.1). Graphical representation of the association shows both decrease and also increase of the incidence of child ill-health with variations of household income (see Figure 6.3).

In other words, both extremes of the relation move in the same direction, that is, negative and positive directions dominate the relationship child ill-health and household income in the aggregated sample from the Ship Channel and South-West residential areas. In other words, in the Houston surveyed households, changes in child health correlated not only with decreasing but also with increasing income. This basic contradiction was a preliminary indication that widespread child ill-health was not only, or necessarily, the consequence of basic socio-economic conditions in the household.

Figure 6.3 Incidence of child ill-health controlling for household income*, Houston, 1990



This unusual pattern begs an explanation of the role of further factors in the incidence of child ill-health.[1]

The role of household geographical location in the relationship between the extent of child ill-health and income was examined because, as established in section 2.6.3, the role of spatial location is important not just as context but for the effects of constructed space on determining social and physical conditions. Spatial variation from this viewpoint has usually been overlooked within social and scientific explanations of ill-health (see section 2.7). This thesis attempts to rectify this shortcoming. We move on now to examine additional household factors which were thought to be influential in the incidence and distribution of child ill-health and to ascertain in what circumstances spatial location was significant in the relationship.

[1]The statistical analysis in this thesis neither run coefficient tests nor indicates levels of variance in order to avoid the cause-effect results derived from these inferential measures.

6.3.2 *Type of Health Care and Medical Expenditure*

In Chapter 1, the world reputation of the 'medical industry' (Greater Houston Partnership, 1995/6) in Houston has been discussed (see sections 3.2.1 and 4.2.3) and in Chapter 5 the contradictions within the US health care system have been established. Access to most, and best, health services in Houston is limited by the high price of the services. It has also been shown that, although provision of public health care is available in Houston, it is deficient for the poor (see section 5.3). Bearing in mind both that a primary objective of the thesis is to reveal the factors which caused child ill-health in the studied population and that provision of health care is insufficient, we need to examine how the type of medical care and the average expenses of the household affect the state of child health in the sample population.

The survey examined whether the household used private or public health care and how this fact affected their children's health. The survey has shown that more private (49%) than public (36%) medical provision was used by the surveyed households (n=300) but households also used both sectors (15%). The incidence of child ill-health was, however, high in households which approached public (74%; n=108), private (63%; n=146), and also both types (67%; n=46) of health care. In low-income households, 70% used the public health delivery system; the private sector was used by only 13%. The remainder low-income households, 17%, used both public and private medicine. In contrast, the private sector was used by 85% of high-income households; public medicine was used by only 2%; and 13% accessed either type of medicine. However, while high-income households spent significantly more financial resources on monthly private health care ($350) than low-income households ($50), the difference in the extent of child ill-health between the two types of households was not as large as one might have expected (21% and 28% respectively).

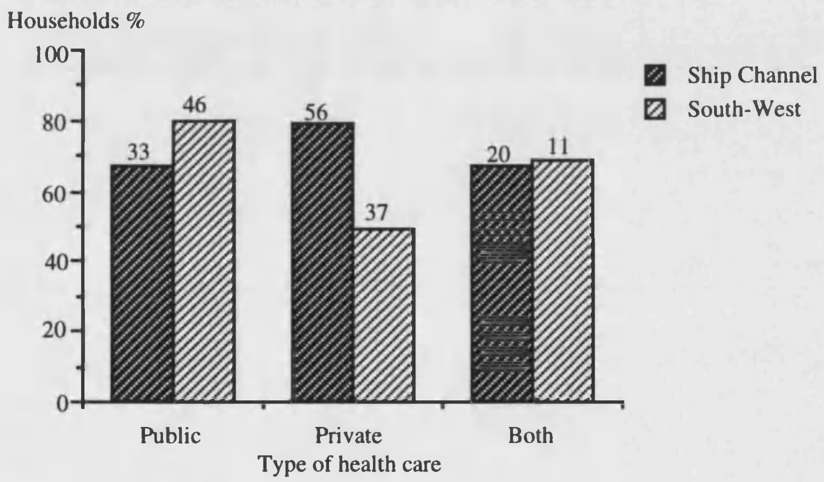
The influence that access to health institutions has on the state of health has been shown for the UK and for the USA (e.g. for the UK: Hart, 1975; Black *et al*, 1982; Hart, 1986; for the USA: Dougherty, 1988; Boone, 1989; Golding, 1986; see section 2.5.1). However, analysis of access to health care provision alone does not seem to be enough. Therefore, the amount the household spent on health care was also assessed to clarify the role of the health care structures in the incidence of child ill-health. The Houston APCHS, 1990, found that many low-income households (29%) reported that it was 'extremely difficult to pay for health care' (11% in high-income households). The sums of money that households allocated to medical expenses varied greatly but correlated squarely with the general income of the household. In fact, among low-income households, monthly expenditure on health amounted to about 5% of the average monthly income ($1,250). In higher income households, about 11% of their monthly income ($3,300) was spent on health care needs (see Table 6.1).

Furthermore, whereas no significant statistical association was found between health spending and the extent of child ill-health in low- and high-income households, these variables were significantly correlated only in households in the South-West ($P<0.04$). In other words, only in the less polluted area did the amount that the household spent on health care make a difference to the state of child health. Evidently, the amount allocated to health cannot, on its own, predict the whole variation of child ill-health found in the sample.

Health provision in the two geographical locations was similarly distributed with public health facilities being accessed by 33% in the Ship Channel and 39% in the South-West; private provision was used by 47% in the Ship Channel and 50% in the South-West. In the Ship Channel, 20% of households used either private or public medicine; 11% did so in the South-West (less households used public provision in the South-West because there was no city clinic in this part of the city; see section 5.3.3). For the purpose of conducting comparative analysis, it was very fortunate that the use of health institutions was so similar in the two selected study areas.

In the less polluted area, the incidence of child ill-health varied according to the type of health care used. Child ill-health was reported in 80% of households that used public health facilities; in 69% that used both public and private health care; and in 49% that used private medical provision only (it is noteworthy that the latter is very high as well, a point which will be scrutinized in Chapter 7). These variables are strongly associated in the less polluted area (P>0.001). In the Ship Channel, on the other hand, the incidence of child ill-health was distributed in quite a different pattern and there is no sign of a statistically significant association between the extent of child ill-health and the type of health provision. First, households that accessed only public health facilities, or used public and private medical care, reported the same incidence of ill-health (67%). Second, 79% of the households which only used private medicine reported child ill-health (see Figure 6.4).

Figure 6.4 Distribution of reported child ill-health and type of health care, Houston, 1990



In summary, the type of health care provision and the household spending on health care may account for the incidence of child ill-health only in the less polluted area. The findings so far point, first, to the clear inadequacies of the US profit-oriented health and welfare system and, second, to the possible presence of additional factors which affect the state of child health in Houston.

6.3.3 *Housing and Health: the Case of Dampness*

One aspect of housing, dampness, was particularly explored because of both very hot and humid climatic conditions in Houston and the spread of usage of artificial air conditioning in most buildings. A note on central air conditioning.[2] There are a number of reasons for the higher percentage of households with central air conditioning in the South-West than in the Ship Channel. First, in the South-West houses have been built more recently and therefore have central air conditioning. Second, most of those on low-incomes in the South-West live in rented apartments which always have central air conditioning and it can be used at no extra charge. In the Ship Channel, on the other hand, many low-income families live in cheap and generally old houses which do not have this facility. Moreover, many highest income houses in the Ship Channel are old and do not have central air conditioning. Air conditioners such as electric units were usually found in these homes. Importantly, lack of natural breathing can be aggravated by the fact that buildings are kept closed most of the time to maintain a pleasant temperature and in this way rooms are not properly ventilated, which may result in residual humidity. For dwellings without central air conditioning the situation is not much better.

It is important to examine the effect of dampness on child health for three reasons. First, one of the most common health hazards associated with poor housing conditions has been dampness (e.g., Macintyre, 1993; Blackman, 1989; Townsend, 1983; Spivey and Radford, 1979; Yarnell *et al.*, 1977; Girt, 1972; see section 2.5). Second, dampness seems to seriously affect the health of children particularly in relation to the level of respiratory/bronchial symptoms. Headaches, diarrhoea, aches

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[2]Air conditioning has played an important role in the city. Hot weather in Houston usually starts in May and lasts until October. Other big cities have higher summer mean temperatures, but few have the humidity levels of Houston. Office air conditioning first appeared in 1923, but most business locations were not cooled until after the Second World War. Central air conditioning was an essential factor to attract business to Houston. Homes, cars and schools were air conditioned in the 1950s and 1960s, followed by other specialized sites in the 1970s. By the mid-1970s, the middle and upper classes had almost completely insulated themselves from the four to five months of severe summer heat and humidity (Thomas and Murray, 1991).

and pains have been more commonly reported among children in damp than dry dwellings (Hart *et al.*, 1986). Mould growth was pinpointed as the factor responsible for the significantly worse state of health of children in damp houses. Spores germinating under moist conditions may enter the respiratory tract, causing bronchial and asthmatic symptoms including fever, tiredness and lethargy. Children then have less resistance to the allergens and are more vulnerable. Third, allergic reactions may occur to the house dust mites and storage mites that multiply in damp conditions. The mycotoxins, or mould given off by fungi, may get into the mouth or nose and be swallowed, causing stomach upsets as well (ibid.).

Altogether, 19% of surveyed households (n=300) reported dampness (13% 'did not know' whether there was dampness in their house) and the distribution was very similar in the polluted Ship Channel and control areas (see Table 6.2). The incidence of child ill-health was particularly high in houses with reported dampness. These findings confirm that dampness is likely to aggravate ill-health, particularly in poor households. Nonetheless, in high-income households with no reported dampness, the extent of child ill-health was surprisingly high.

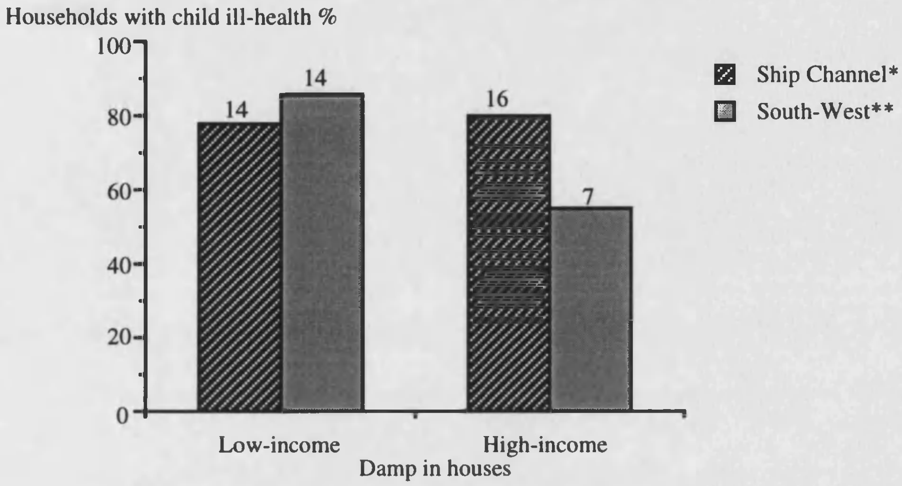
Table 6.2 State of child health by household income and reported dampness by area, Houston, 1990

Households	*Total households* *	*Ship Channel*	*South-West*	*Child ill-health*	*No child ill-health*
Low income					
Damp in house	n= 34	n=18	n=16	82%	18%
No damp in house	n=106	n=57	n=59	71%	29%
High income					
Damp in house	n=25	n=14	n=11	67%	33%
No damp in house	n=118	n=61	n=64	58%	42%

*19 cases 'did not know' whether there was dampness in the house; 2 observations were missing

The incidence of child ill-health in damp houses (n=45) was higher in the Ship Channel (70%) than in the South-West area (60%). Ill-health in low-income damp houses in the Ship Channel and in the South-West was similar and very high (79% and 83% respectively). This could be attributed to social disadvantage. On the other hand, in high-income damp houses, the incidence of child ill-health was 25% higher in the Ship Channel than the South-West area (see Figure 6.5).

Figure 6.5 Spatial and social patterns of child ill-health in damp houses, Houston, 1990



The conclusion to be drawn is that dampness in the house might have contributed to child ill-health (since the number of houses with declared dampness was relatively small in the studied population, it was not possible to run inferential statistics). Nonetheless, the comparative study revealed that the absence of dampness in the house did not preclude such households from reporting high incidence of child ill-health (67%). Second, contingent variables, i.e. household income together with spatial location, indicated significant features of the distribution of this incidence.

There is thus an indication that, in the presence of dampness, the conditions for ill-health might have been aggravated. So far, the type of medical care, health expenditures, household income and dampness in the house have been instrumental in two senses: in identifying the patterns of variation of child ill-health, and in accounting for a significant section of the incidence. We need now to search for further factors which may explain child ill-health in the rest of the households with reported incidence.

6.4 Occupational Class and Health Variation

Four remarks should be made at the outset about social class, or 'more accurately, occupational class' (Black *et al.*, 1982, p. 48). First, it has been established in Chapter 2 that social class is a composite generalization which by itself cannot explain the outcomes (see section 2.5.4). Therefore, in order not to confuse the issue of causality, the focus of the analysis of social class and ill-health has been on the type of occupation in which the mother was engaged as well as on the income and location of the household.

Second, three considerations were important for examining the mother's, and not the father's, occupation as an indicator of socio-economic status of the household. First, according to the City of Houston Health and Human Services Department annual report (II, 1988, pp. xv-xvii), the percentage of households headed by single mothers in Houston was approximately 13%, which is remarkably high. Indeed, had the thesis focused on the occupation of the father, as most studies do, there would have been problems because there was no father figure in 21% of the surveyed households (see Table 6.1).

Third, mothers were the focus of reporting because, generally, they spend more time with their children and often they are more aware than fathers of their children's health needs. Also, mothers usually give more explicit and concise information about child health and about the social circumstances of the household. Finally, by focusing on the mother's, and not the father's occupation, the thesis wishes to convey that the activity of the mother is economically and socially of great relevance to the functioning of the household. In the British census, housewives, or full-time unpaid domestic workers, have been grouped under the category 'other economically inactive' despite their economic and social importance. Duncan (1991) has estimated that if the totals of housewives and women of independent means in the UK, both sub-categories of 'other economically inactive' in the census, were added to the economically active total, the economically active census figure for women would almost double. The APCHS in Houston found that 50% of household income variation was associated with the occupation of the women (P=0.000). This reinforces the choice of the mother's occupation as a class indicator for analytical purposes.

In the thesis, the mother's occupational class has been classified in five categories. The categorization broadly corresponds with the social class categories of the British Registrar-General (BRG, 1971) which has been widely used elsewhere. The main reason which prevented the author from strictly adhering to the same categories of the BRG was that the traditional classification in the BRG only allows for employed individuals who are defined as economically active workers.[3] As a result, mothers who are not formally employed, but have full-time unpaid work at home, are automatically excluded from the BRG classification. The premise was thus that housewives in the surveyed households played active social and economic roles. Therefore, the 'full-time domestic occupation' category was added to those that were chosen from the BRG. Initially, occupational classes were classified in six categories. However, because only a few mothers were 'voluntary and students', this category was collapsed into 'professional'. The final occupational classification used in this thesis is thought to be most appropriate to analyze the population surveyed:

I. <u>Professional</u>. Highly skilled and with highest social status. Academic occupations such as medical, technical, scientific, artistic, etc.

II. <u>Intermediate</u>. Skills needed but lower in social status. For example, managerial positions, nurse, school teacher.

III. <u>Semi-skilled</u>. Manual and non-manual. Mainly found in the service sector, such as shop assistant, clerical work.

IV. <u>Unskilled</u>. Paid domestic work, gardener, factory machine operator.

V. <u>Domestic</u>. Mothers who are not employed. Their main occupation may consist of unpaid full-time house-work, child-care, and more. House-work requires manual

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[3]The categories in the BRG are: I.Professional; II.Intermediate; IIIN. Skilled non-manual; IIIM. Skilled manual; IV. Partly skilled; V. Unskilled.

as well as non manual skills and therefore is difficult to categorize. Despite the fact that also among high-income households there are unemployed mothers, the occupational domestic category has the lowest status on the scale (the researcher, though, has reservations).

6.4.1 *Mother's Occupation and the State of Child Health*

The incidence of ill-health which corresponded to each occupational class, disregarding any further qualifications, is displayed in Table 6.3.

Table 6.3 Child health and the mother's occupation, Houston, 1990

Occupation category	*Households in each category**	*Households (%) **with** reported child ill-health*	*Households (%) **without** reported child ill-health*	*Total (%)*
Professional	54	61	39	100
Intermediate	38	74	26	100
Semi-skilled	80	65	35	100
Unskilled	21	67	33	100
Domestic	100	72	28	100
Total	293			100

Large percentages of unhealthy children were reported for practically all occupational classes, a fact indicative of the presence of a severe health problem. In households where the mother worked in a professional occupation, child ill-health was, as expected, lower than in the rest of the surveyed households. The higher incidence of child ill-health was found in households of lower occupational status, and this fully agrees with the influential argument that social inequality is the main trigger of ill-health (see, for example, Blaxter, 1990, 1975; Townsend *et al.*, 1988; Hart, 1975; see section 2.5).

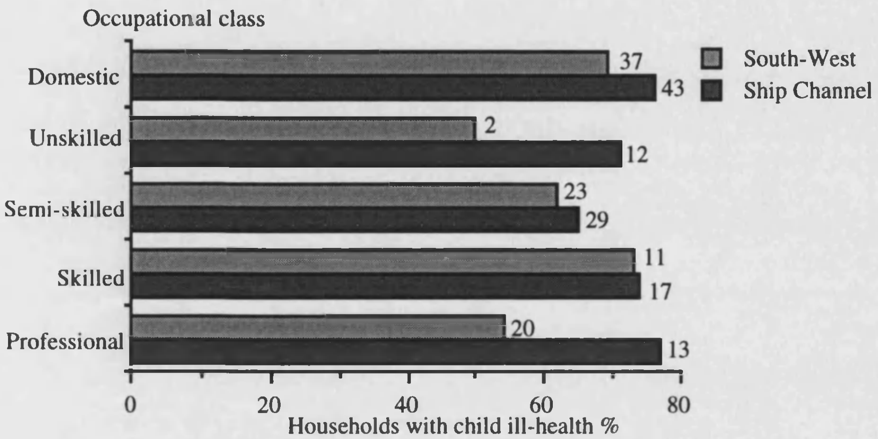
Returning to the issue of housework, these findings, however, should not mislead us into concluding that 'housework', as a skill and occupation, increases the risk of illness. Instead, the state of forced unemployment, which usually accompanies housewives particularly in low-income households, invariably results in additional poverty, and consequently, in more child ill-health. In Houston, 'housewives' in low-income households frequently stay at home because they are immigrants and have precarious knowledge of English; or their illegal residential status in the USA impedes them from competing for better-paid jobs. A further obstacle is the lack of affordable child day-care facilities in Houston (Hardikar, personal communication, 1992; see section 5.3.3). In high-income households, conversely, many mothers are not engaged in paid jobs precisely *because* of their high social status and are not expected to work for money. Therefore, high incidence of child ill-health found in lowest occupational categories might be attributable to disadvantageous conditions rather than to occupational class itself. Nonetheless, child ill-health in these households was higher only by 11%-14% than for the children of those mothers in the most prestigious occupational categories. Therefore, the distribution of child ill-health along the type of occupational class, independent of other conditions of the household, has proven insufficient evidence to explain the presence of child illness in the study households.

6.4.2 *The Combination Effect*

Comparison of the combination effect of household income with the mother's occupational status indicated a clear relation to the extent of illness. A negative and robust association was found between the incidence of child ill-health in poor households and the occupation of the mother (P=0.000). Among the highest occupational classes, however, there was no clear evidence that the occupation corresponded with a significant decrease in child ill-health. This finding was unexpected because it did not match the claims in the literature.

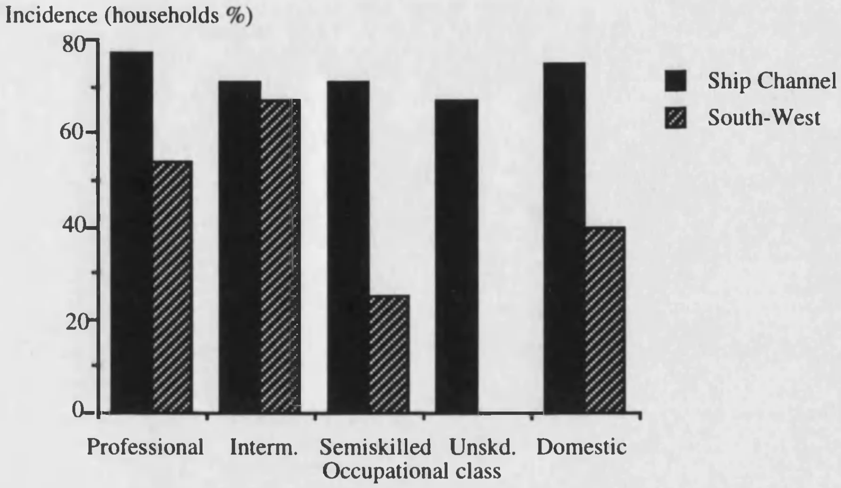
Examination of the particulars of the geographical distribution of the incidence of child ill-health threw new light on the findings. First, while the occurrence of occupational classes was similar in the two geographical areas (see Table 6.1), at the outset, for each occupational category, the incidence of child ill-health was higher in households in the Ship Channel, near the sources of industrial pollution, than in the South-West (see Figure 6.6).

Figure 6.6 Spatial distribution of reported child ill-health by mother's occupation, Houston, 1990



Second, low-income households in the Ship Channel and in the South-West reported a similar incidence of child ill-health (for intermediate, semi-skilled, un-skilled, and domestic occupations, 83%, 64%, 71% and 77% respectively in the Ship Channel; 100%, 72%, 67%, and 80% respectively in the South-West). Similarity in the geographical distribution of the incidence could be attributed, primarily, to the effects of poverty. However, the spatial variation of the incidence of reported child ill-health was particularly pronounced among highest income households (see Figure 6.7). In the professional group, there was 23% more child ill-health in the Ship Channel than in the South-West. In the domestic category, 35% more households in the Ship Channel than in the South-West reported ill children. The percentage of child ill-health reported by mothers in semi-skilled professions was 46% higher in the Ship Channel. Very few mothers in high-income households in the Ship Channel worked in un-skilled occupations (n=3) (one worked in the South-West). Reported ill-health was 67% in the Ship Channel and 0% in the South-West. There was thus a strong indication that other factors which varied by the geographical location of the household were relevant in the association.

Figure 6.7 Spatial distribution of child ill-health in high-income households by mother's occupation, Houston, 1990



In summary, the effect that occupational class had on the variation of child ill-health corresponded with the general income status. Nonetheless, this combined effect was consistently modified by the spatial distribution of the household. Since spatial location *per se* cannot cause ill-health (see section 6.3), the presence of causal factors which may have varied by location seemed the most likely explanation. Before finally moving to examine the effect of spatial variation, the role of demographic characteristics and spatial location of the household on the incidence of child ill-health will be assessed.

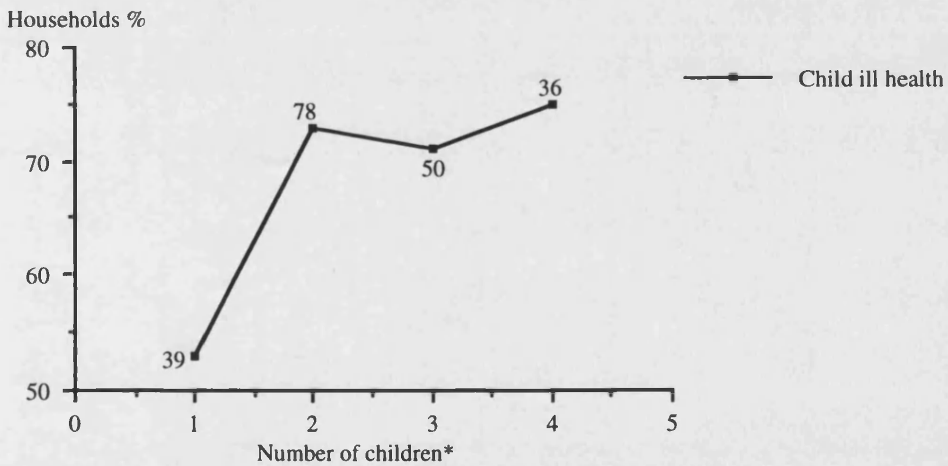
6.5 The Role of Demography and Family Structure

Two structural family factors, the number of children in the household and parental composition, were assessed for their prospective effects on the state of child health. Household size is apparently highly interrelated with ill-health in that infections are more likely to be introduced into larger households, with the risk of child illness increasing as the number of children in the household rises (Butler and Golding, 1986; Leeder *et. al.*, 1976; Harlap *et al.*, 1973) (see section 2.5.2). However, the APCHS shows that the number of children who live in the household, and whether one or two parents headed the household, correlates, above all, with household income. In the present section, the effect of these two socio-demographic variables on child health will be investigated. A comparison will be made between low- and high-income households near to and far from sources of environmental contamination.

6.5.1 *Health Effect of Number of Resident Children*

The chance of finding ill children increased remarkably as the number of children in the household rose from one to two. Overall, there was 20% more child ill-health in two- (73%) than in one-child households (53%; n=75). In two, three, and four and above children households (n=105, n=72, and n=48 respectively), the incidence of ill-health was very high but it did not change proportionate to the rising number of children (73%, 71%, and 75% respectively) (see Figure 6.8).

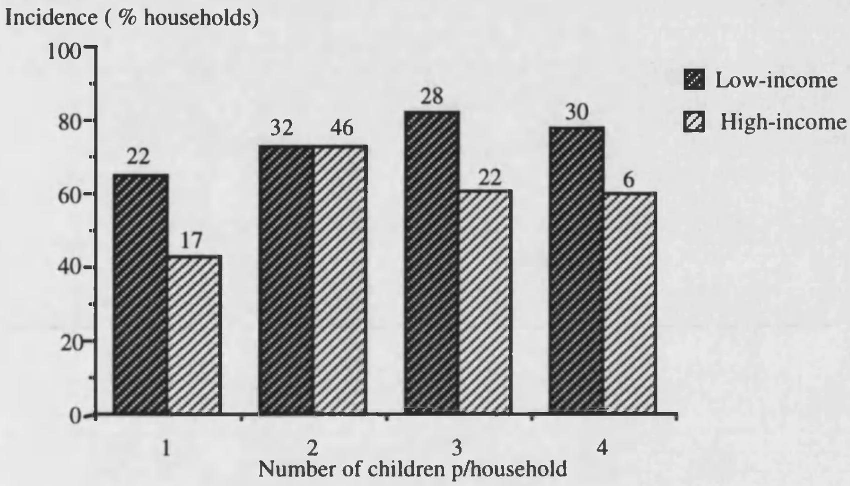
Figure 6.8 Child ill-health and number of children in household, Houston, 1990



What was the incidence jump from one child to two children households indicating? Why was the incidence so similar in two, three, and four and above children households? Clearly, the incidence of child ill-health combined with the number of children living in the household, without further specification, confuses rather than clarifies the role of this factor. Further specifications were thus needed in order to understand the actual contribution of this factor.

The relationship between the incidence of child ill-health and the number of children in the household was compared in different income households. It was learnt that the extent of ill-health was considerably higher in low- as opposed to high-income households, but that rising number of children did not seem substantially and directly to affect all the incidence (see Figure 6.9).

Figure 6.9 Variation of reported incidence of child ill-health by low- and high-income household (n=300)* according to number of children resident, Houston, 1990

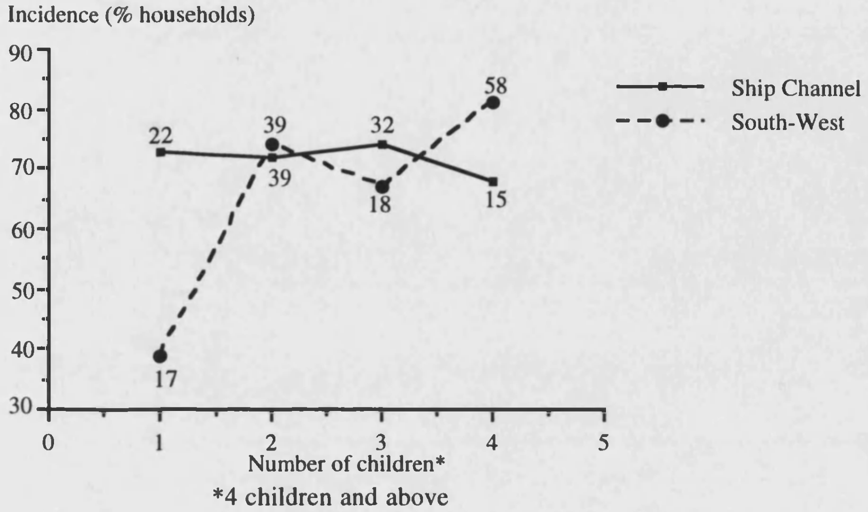


*1 missing case

** Category 4 on the horizontal axis means 4 or more children

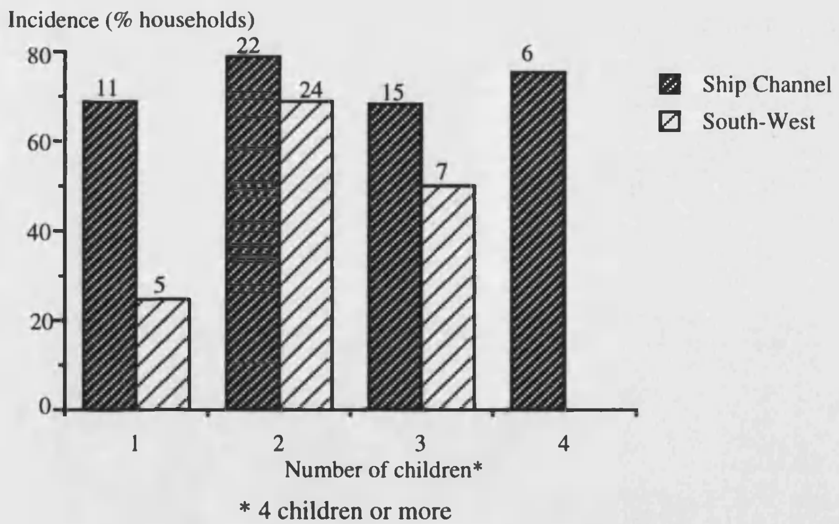
The combined effect of the number of resident children and spatial exposure was assessed by comparing the relationship in the Ship Channel and in the South-West. Altogether, child ill-health was very high in the air polluted area particularly for one- and three children households; it was however slightly higher in the South-West for two and four and above children households (see Figure 6.10). Higher incidence in the less polluted area might be attributed to poverty (see section 6.2). Significantly, only in the South-West are the variables child ill-health, household income (P=0.009), and the number of children in the household (P=0.000) statistically associated.

Figure 6.10 Spatial variation of reported child ill-health by number of children in household, Houston, 1990



Focusing on the incidence of child ill-health in highest income households only was illuminating. It was found that child ill-health was 40%, 10%, and 38% higher in one-child, two-, and three-children households respectively in the Ship Channel than in the South-West (see Figure 6.11).

Table 6.11 Spatial variation of reported child ill-health by resident children in high income households, Houston, 1990



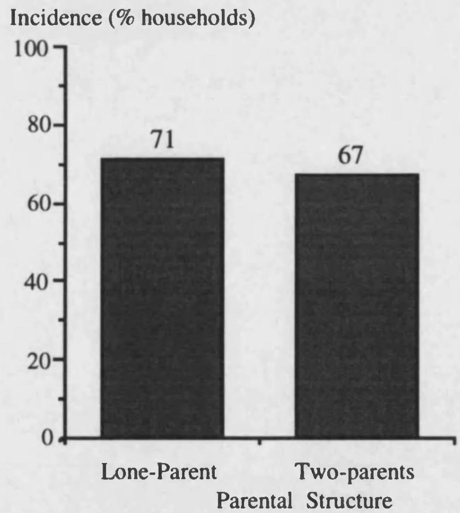
The number of children in the household and household income acted as partial indicators of the extent of child illness. However, the extent of the incidence of child ill-health in the Ship Channel remained unexplained by these indicators alone.

These findings indicated that there were causal factors which varied by location and were influential in the pattern found.

6.5.2 *Parental Structure and Health of Children*

As previously stated, single (female) headed households in the sample population were very numerous (21%) and the survey found that there was no correlation between parental structure *per se* and the state of child health. Child ill-health was only 4% higher in single than in two parent households (see Figure 6.12). In general, this finding agrees with Blackman *et al.* (1989). In a housing and health study in West Belfast, they found no significant difference in the health of the children of one-parent compared to two-parents households.

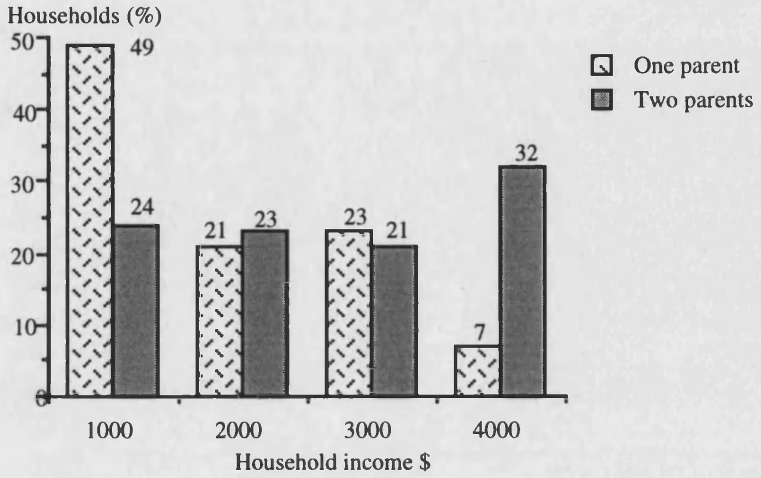
Figure 6.12 Incidence of reported child ill-health and parental structure*, Houston, 1990



* Lone parent households n=63 ; two parents households n=237

As to average household income, half of all lone-parent households (49%) reported low income whereas only a small fraction (8%) earned high incomes (20% reported incomes in the second low income bracket, and 22% in the third) (see Figure 6.13).

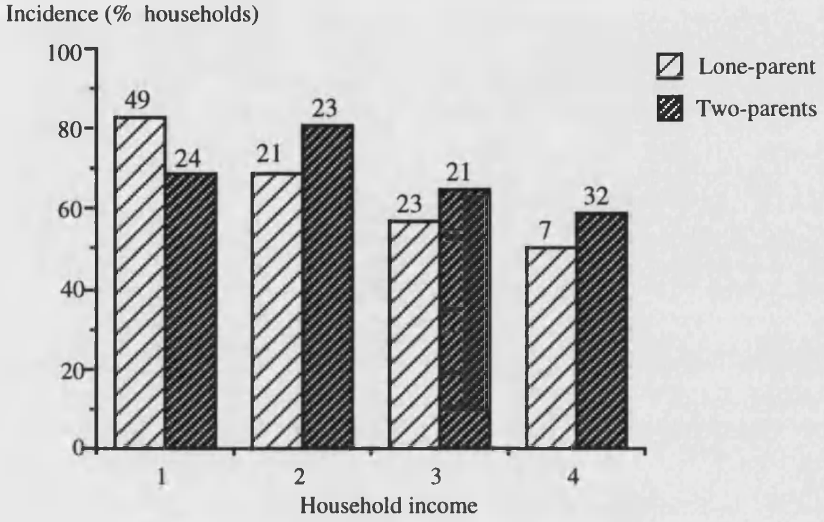
Figure 6.13 Household income and parental structure, Houston, 1990



These figures closely agree with the Children At Risk Committee's (1990) report on poverty and single parenthood in the state of Texas which found that 42% of single-parent households lived below the poverty line and an estimated 76.8% of all single mothers under the age of 25 lived in poverty .

When parental structure was examined together with income and spatial location of the household, the effects of parental structure became more obvious in two ways. First, clearly, there was more child ill-health in low- than in high-income single-parent households (22%). However, incidence of child ill-health was not significantly smaller in low-income two-parents households (see Figure 6.14). In the rest of the households, child ill-health was generally lower in one- than in two-parent households. There was clearly a causal relation between the economic resources of the household and parental structure, and this particular relation seemed to have an effect on the state of health of the children.

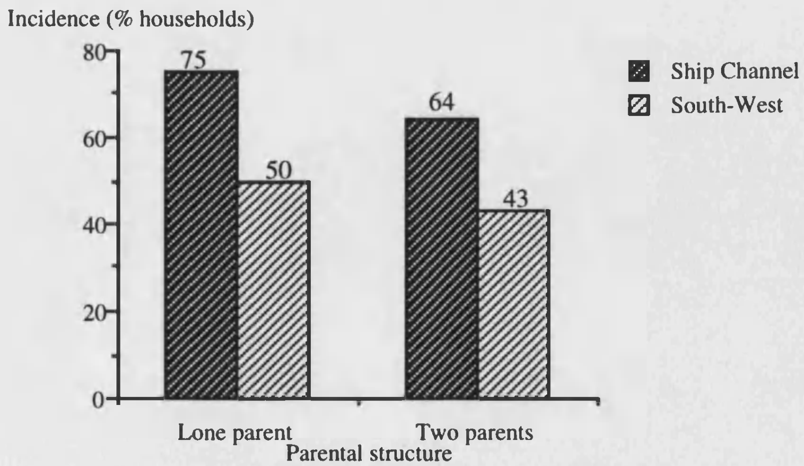
Figure 6.14 Variation of reported child ill-health by parental structure and income bracket,* Houston, 1990



*see section 6.3.1

Second, the distribution of child ill-health in single and two-parent low income households was very similar in the Ship Channel and the South-West residential areas (for lone-parent, 70% and 78%; for two-parent, 78% and 78%). However, in high-income households, more child ill-health was found in the Ship Channel than in the South-West residential areas in both single and two-parent households (see Figure 6.15). These findings clearly indicated the strong influence of local variables.

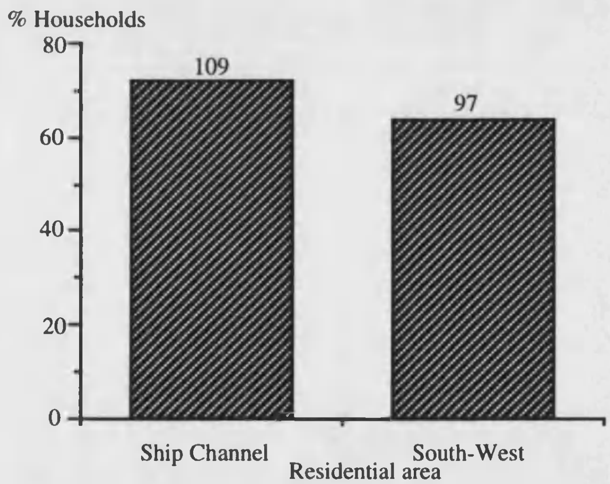
Figure 6.15 Distribution of reported child ill-heath by parental structure in high-income households (n=150), Houston, 1990



6.6 *The Crucial Role of Household Location*

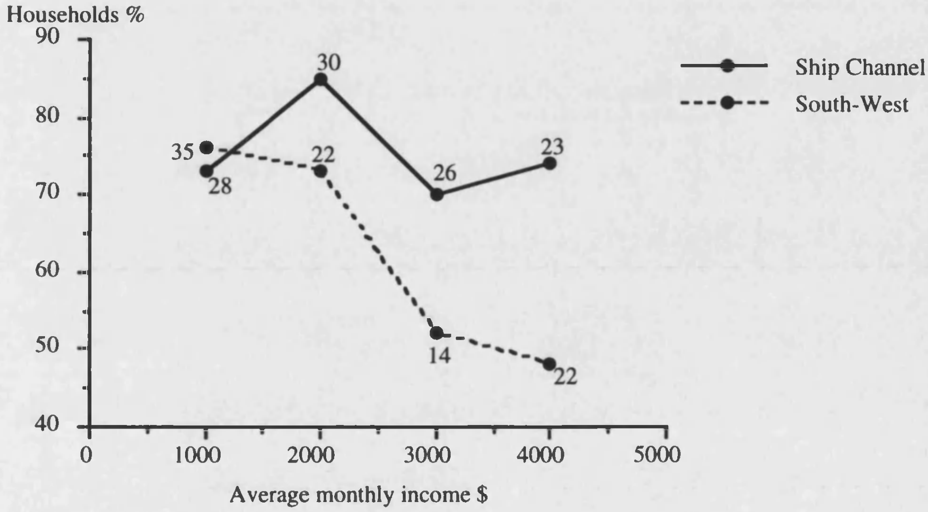
Comparative analysis has shown that social and other contingencies were further modified as the result of particular spatial location of the household and the length of circumstantial exposure to local and occupational risks. Analysis of the role of household location was essential because social, spatial and environmental changes are integral to each other (see section 2.6). Comparative study determined whether there is any noticeable geographical pattern in the distribution of households with reported ill children. Significantly, 10% more households (n=150 households) in the Ship Channel residential area (i.e., those near to sources of industrial air pollution) than in the South-West (n=150 households; relatively far from sources of industrial air pollution), reported child ill-health (73% and 63% respectively) (see Figure 6.16).

Figure 6.16 Distribution of reported child ill-health, Houston, 1990



Analysis of the geographical distribution of child ill-health accounting for different income per household shows that child ill-health was similarly and significantly (P< 0.003) distributed in lowest-income households in the polluted as well as in the less polluted areas (72% and 77% respectively) (see Figure 6.17). Moreover, and perhaps most importantly, the following findings show a strong correlation between the location of the household and the incidence of reported child ill-health. First, while in the South-West the extent of child ill-health decreased with rising household income, in the Ship Channel area the incidence remained high with rising household income. Second, child ill-health was remarkable in all high-income households, 61%. Third, significantly, while there were 10% more households with reported child ill-health in the Ship Channel, the incidence of reported disease was 24% higher in wealthy households in the Ship Channel than in the South-West (n=453) (73% and 49% ill-health in the Ship Channel and in the South-West).

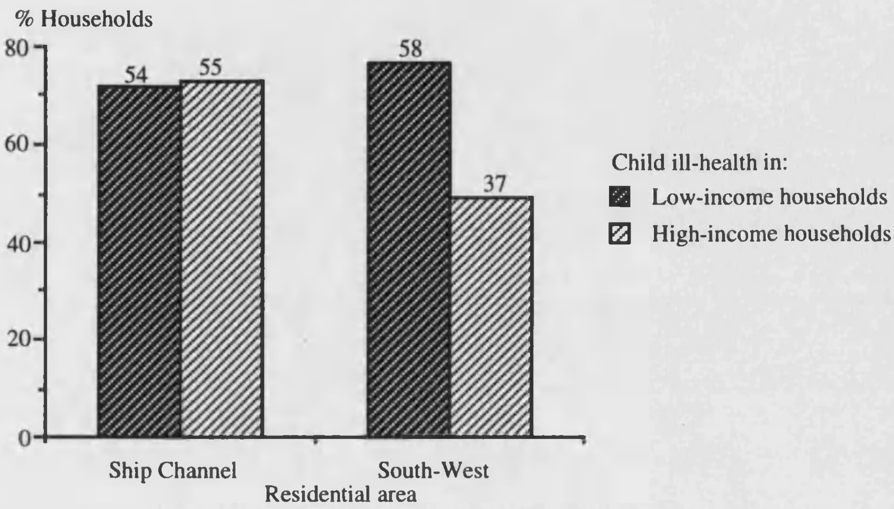
Figure 6.17 Distribution of child ill-health by household income, Houston, 1990



Therefore, despite the higher numbers of ill children found among poor households, household income could not act as an accurate and convincing predictor of the incidence of child ill-health (see Figure 6.18).

Evidently, geographical location in relation to industrial sources of air pollution played an important modifying role in the extent of ill-health in the surveyed households. While it has been established that spatial location *per se* cannot account for the events, it can make a crucial difference to how social and other processes work and to what forms result (Duncan, 1989; Sayer, 1985; Massey, 1984) (see section 2.6.3). Therefore, we need to examine whether there are particular social or physical conditions present in one area but not in the other that made spatial household location relevant.

Figure 6.18 Spatial and social distribution of reported child ill-health, Houston, 1990



6.6 Conclusion

Chapter 6 has examined micro-economic characteristics of the household in order to assess whether clues to causality emerge in relation to the incidence of child ill-health found in the Ship Channel and South-West areas. Whilst the survey has found very high incidence of child ill-health in the sample households in general, the comparative analysis has uncovered, first, that, as expected, the incidence of illness among poor children is always very high, indicating that social inequality was an important factor. Second, one of the most revealing of the findings is that the incidence of ill-health in all high-income households was unexpectedly high. Third, considerably more than expected child ill-health was reported in high-income households in the Ship Channel, that is, as compared to the South-West, in the most air polluted area.

The distribution of reported child ill-health in households in the less polluted area always correlates, as expected, with household socio-economic and demographic circumstances. Indeed, in the South-West, the extent of child ill-health diminished if the household had higher income, fewer children, higher occupational status, and two parents. In contrast, child health variation in the Ship Channel did not change consistently with different social and demographic household circumstances such as household income, the number of resident children, the mother's occupation, and parental structure. In summary, poverty always has an active role in triggering ill-health. However, it was the large incidence of reported child ill-health in high- compared to low- income households which revealed the crucial role of additional risk factors of a spatial character (P=0.014). This was significantly expressed in the geographical distribution of child ill-health in regard to socio-economic and demographic variables related to ill-health (P=0.001). The combination of various socio-economic and demographic circumstances of the household with the location of the household in relation to the industrial complex in Houston seemed to offer causally relevant information in order to elucidate the origin of high incidence of child ill-health in Houston.

Widely accepted assumptions about the role of socio-economic structural conditions in the household have proven helpful, but not sufficient to understand the regularities and irregularities that have emerged from the household survey in Houston. Without denying that poverty is a main cause of ill-health (see sections 2.5, 5.3 and 6.3.1), these fundamental assumptions should be reconsidered in the light of the findings of the thesis' household survey. Explanations based on social disadvantage alone were not valid for understanding the unexpected incidence of child ill-health in wealthy households in the air polluted area. Spatial location of the residence was crucial for identifying how social factors acted in relation to the reported incidence of child ill-health.

However, it is not spatial location *per se* which accounted for the distribution of child ill-health because, as stated in Chapter 2, 'spatial relations are still secondary and contingent, even if primary, generative causal mechanisms are spatially bounded' (Duncan, 1989, p. 135). The pattern of spatial variation of child illness in Houston reflects the interaction of causative physical and social processes. But these operated outside the boundaries of the household. Two main spatial features made one location different from the other. First, the proximity of the household to the large petrochemical industry (see section 5.4); and second, the environmental quality of outdoor air (see sections 4.4). The next chapter will examine local environmental conditions and their direct effect on child health and the structural links of spatial patterns of risk.

CHAPTER SEVEN

THE RELATIONSHIP BETWEEN AIR POLLUTION AND CHILD ILL-HEALTH

7.1 Introduction

A survey of the people who live in the Ship Channel can be much more reliable than measures of emissions (McMullen, Director of the City of Houston Air Quality Control Board, personal communication, 1992).

The household survey has shown that whilst the socio-economic circumstances of the household were significantly associated with the incidence of child ill-health, spatial location *vis-à-vis* air pollution sources was highly important in the determination of causality trends. It is the aim of this chapter to focus on the relation between child health and environmental pollution, and in this way to substantiate two claims. First, that child ill-health in the surveyed Houston households can be understood as the result of collective, rather than individual, exposure to moderate and often high levels of pollution, and second, that the particular spatial distribution of child ill-health that was a feature of the sample households in Houston indicates structural processes due to the presence of the huge petrochemical complex and port facilities in the Ship Channel region.

As established in the causal model, the effect of spatial location of the house on child health is that of modifying rather than causing the events (see section 3.3). The current research draws on the assumption that causality is concerned with more than simply establishing statistical correlation (see section 2.8.3). Wherever possible, we try to get beyond the recognition that something produces some change to an understanding of what it is about the object that enables it to do this (Sayer, 1992, p. 106). While this suggests that the value of statistics is depreciated as our knowledge of causal mechanisms becomes more complete (Harré, 1970), statistical methods may still be used to model the relative quantitative dimensions of this group of social and spatial associations in Houston.

Chapter 7 first discusses the issue of air pollution in the study areas, examines the degree of air pollution that residents reported and compares it with measured monitored air pollution, and assesses residents' reasons for living there; second, it examines both the spatial patterns and the type of health effects directly associated with rising air pollution; third, exposure to both environmental occupational hazard and to tobacco smoke are explored. Particular attention will be given to exposure to tobacco smoke, as it has increasingly been recognized for its deleterious health consequences (Hoppenbrouwers, 1990) and has attracted most political attention. It is argued that there is a general confusion as to the health impact of passive smoking in the presence of air pollution which jeopardizes the ascription of causality of increasing child ill-health in cities.

Three additional claims are made in this chapter. First, air pollution has been recognized as an outstanding problem in Houston (see section 4.4), the biological sciences have revealed mechanisms of air pollution that damage health, and the health impact of air pollution on the population is being increasingly acknowledged (see section 2.4). In Houston, the main source of environmental contamination has been extensive industrialization and energy usage. It is argued that the analysis of this information has, however, failed to combine the pieces in a framework which is political and causal. Local residents provide crucial information to determine the causal linkages of the incidence of child ill-health, environmental pollution and economic development. It is argued, however, that the relationship between industrial air pollution and child ill-health is essentially a window on the effects of the more general process of economic growth and environmental degradation. The contribution of Chapter 7 thus lies in the fact that the original information on local air pollution and ill-health will here bridge the existing gaps and connect different bodies of knowledge.

7.2 Residents and the Environmental Problem

Monitored and reported levels of air pollution in the surveyed areas in Houston will be analyzed within a comparative framework. This is necessary to establish whether, and under which circumstances, ecological mechanisms are activated to cause ill-health (see section 3.3). Moderate to high levels of pollution have prevailed in Houston since at least official records started in the 1970s. The NAAQSs have been constantly breached, and ozone levels are among the highest in the USA. The PSI > 100, designed to protect health has been repeatedly exceeded during the period between 1984 and 1993 (see section 4.4). The origins of environmental degradation have been traced to the damaging character of the oil industry in particular and to economic growth in general (see section 4.2) which has consistently weakened attempts to regulate toxic emissions (see section 5.2.1). The section argues that the information gathered by the governmental agencies' monitoring system and the knowledge collected in the household survey complement each other. They provide descriptive and also causal information to explain the relationship between air pollution and child ill-health in a major developed city. A few comments from the residents reinforce this argument.

7.2.1 *The Issue of Local Air Pollution*

> *We always have the smell of the refineries. You know, the smell from the Ship Channel (quoted from a resident in a low-income household in the Ship Channel).*

The Houston refineries, petrochemical works, and extended industrial developments, located within a huge area 25 miles long on the east side of the city (see Figure 4.5), are the legacy of rampant industrial development and the indisputable source of large amounts of toxic chemicals emitted into the air, as established in Chapter 4. Environmental complaints by local residents on the grounds of nuisance caused by pungent chemical smells have officially been forwarded to the City of Houston AQCB. Although the reason for complaint may cite bakeries, garbage, neighbours and so forth, most complaints are triggered by industrial activity (e.g., smell from the refineries, spills of transported toxic materials, explosions in chemical plants; see section 4.5.2). In the household survey, residents have clearly acknowledged the presence of air pollution in their local environments and have qualified it as a real nuisance. Altogether, 79% (n=300) of the sample population reported air pollution (only 2% were not able to give an opinion and 17% reported that they had not noticed air nuisances).

Air pollution may had been even worse than reported. Two relevant factors may have impeded this recognition. First, some airborne toxic substances are either odourless, or their typical odour cannot be associated with noxious materials. Such is the case of ozone, a highly pollutant gas formed in the atmosphere from the combination of nitrogen oxides, additional toxic components, and sunlight. The odour of ozone resembles, in fact, the 'smell of the air after a summer storm' (McMullen, personal communication, February 1992; see Appendix A.3). Therefore, in spite of the fact that ozone concentrations may reach high levels in both the Ship Channel and the South-West, as shown in Chapter 4, it can hardly be distinguished by the residents. On the other hand, sulphur dioxide, carbon monoxide and particulate matters which reach high levels of concentration particularly in the Ship Channel can be more easily singled out. Residents may therefore recognize more readily this pollution but may easily miss the presence of atmospheric ozone. In this way, some air pollution in the air may remain unidentified and, therefore, will not have been adequately reported in the household survey.

Second, the disguising effect of other types of very localized air pollution may occlude the presence of chemical environmental pollution. In the household survey, stench from communal dustbins and also from sewage was the commonest nuisance reported apart from air pollution. Only 16% of the surveyed households reported air nuisances other than chemical. In particular, garbage odour was very disturbing for 13% of the interviewed population with sewage being the source of unpleasant smells for 2% of the respondents (see Table 7.1). Out of all low-income households in the less polluted South-West, 37% (n=75) of the respondents complained of unbearable 'dustbin odours'. Also in the South-West, but in high-income households, residents reported odours from sewage (8%). They attributed this stench to the Braes Bayou, a nearby polluted stream which cuts across the city. In the polluted area, only a few households (4%) reported odours from garbage and sewage.

The issue of air pollution has gained a certain degree of government attention due to complaints from the residents (TACB, 1993b). In December 1992, the TACB appointed a 'Nuisance Odours Task Force' (NOTF). Apparently, one of the main reasons for the creation of the NOTF was the 'public's desire for action' (ibid., p. 4). The new department in the TACB intended to formulate a basis for new policy on 'what members agree is a difficult, subjective area of regulation'. The main plans of the force were to study new advances in measuring odorous air pollution as well as methods to assess the severity of such odours. Despite the evident importance of the task of this agency, it was only empowered by managerial and technological tools; and because air pollution is interpreted only as a nuisance, rather than a hazardous condition which may expose the population to great health risks, the force's scope for bringing about changes is narrow. Indeed, tracking nuisance odours to a specific source seemed a difficult task for the NOTF:

> ***Odours come and go with the wind and come from various sources, so at times it's hard to track down what the source is. We really respond quickly now as a local pollution control program, probably within minutes sometimes. But often we have not been able to confirm, to the satisfaction of the complainer, that a nuisance actually existed (ibid., p. 4, NOTF).***

In comparison with the two other regional surveys which dealt with the pollution crisis in Houston, the HAS and TES, discussed in section 4.5.3, the

APCHS, is the only survey out of the three which was able to demonstrate that, most significantly, the spatial location of the household in relation to sources of industrial emission was crucial in reporting concerns over air pollution. Indeed, air pollution was the most frequently reported preoccupation in the polluted study area, the Ship Channel (49%; n=150; other preoccupations were personal safety - fear of robbery, crime and drugs, water pollution, quality of local schools, and health care). In the South-West, which is less polluted, the worst problems reported in order of frequency of citation were personal safety followed by water pollution, and air pollution came only third (15%; n=150). The APCHS revealed that more high-income - 62% in the Ship Channel, and 78% in the South-West - than low-income households showed concern over air pollution. Nonetheless, reporting of air pollution as the worst local problem was remarkable in low income households, 38% in the Ship Channel and 22% in the South-West. This is a notably high percentage for low-income households because preoccupations such as environmental concerns would be expected to be over-shadowed by health care or personal safety. The degree of reporting indicated that the level of environmental pollution to which residents were exposed in Houston in general, and in the east side of the city in particular, must have been considerable.

7.2.2 *Monitored and Reported Air Pollution*

In order to compare and integrate the extent of air pollution reported by residents with that measured by the governmental agencies, the household survey and the 1990 reports from five monitoring sites are analyzed. The government sites widely correspond to the geographical clusters selected for the household survey (see Figure 3.2). Although not all the US standard pollutants have been sampled regularly in the Houston area during 1990, complete records are available for ozone and sulphur dioxide. Fortunately, these alone can certainly reflect the distribution of air pollution in the city (see Table 7.1).

Table 7.1 Levels of pollutants* monitored in the Ship Channel and in the South-West, Houston, 1990

	O_3	CO	SO_2	NO_2	PM10
Location	High hr	2nd 8 hr	Annual/ 24 hrs	Annual	Annual
NAAQS	**0.12**	**9**	**0.03**	**0.053**	**50**
Ship Channel East					
Clinton	0.23	5.2	0.008	0.024	44.7
Crawford	0.22	7.9	0.006	0.029	30.3
Ship Channel South-East Monroe	0.23	N/S	0.003	N/S	28.0
Ship Channel North-East N.Wayside	0.23	N/S	0.006	N/S	N/S
South-West Croquet	0.22	N/S	0.002	N/S	N/S

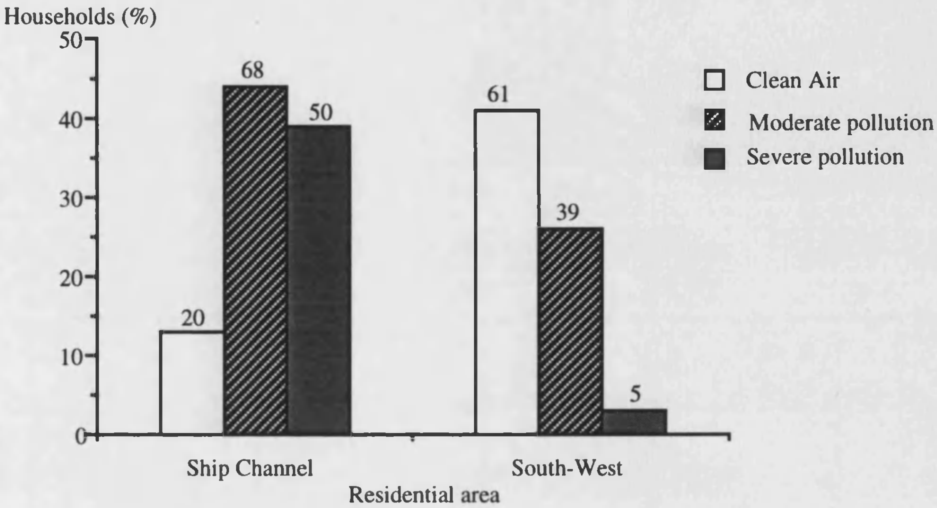
Source: Data from TACB, 1993, Air Monitoring Report, 1990, Texas Air Control Board; and AQCB (1991) 1990 Annual Report, City of Houston Department of Health and Human Services.
N/S: Not Sampled
*** Lead is not included in the table because levels have not been exceeded in Houston**

One interesting point to be noted here is that remarkably more sulphur dioxide was measured in the Ship Channel compared to the South-West. Ozone, however, was very high in both areas. It should be remembered that ozone spreads out and that concentrations of ozone found in the South-West side of the city had partly been displaced from the petrochemical plants, as the 10-year study by the City of Houston has demonstrated (see section 4.4.1). The next noteworthy issue is that the extent of air pollution which interviewed residents reported seems to be fully backed up by the measurements originated in monitoring machines.

At the outset, a strong statistical association was found between reported air quality in the surveyed households and the spatial location of the household (P=0.000). This indicates that geographical location might be influential in the extent of reported air pollution. While the overall percentage of households that reported local air pollution was remarkably high, air pollution in the Ship Channel was twice as heavily reported (85%; n=150) as in the South-West (42%; n=150).

Also the degree of reported severity of air pollution varied from area to area (see Figure 7.1).

Figure 7.1 Distribution of reported air quality, Houston, 1990



The severity of air pollution was determined by the extent to which the air was pungent, and the frequency with which it became polluted. In the polluted area, severe and moderate air pollution was reported (34% and 49% respectively). In the less polluted area, considerably fewer households reported severe (5%) compared to clean (42%) air pollution. While some households also reported other types of air nuisance (e.g., odour from dustbins, sewage), clean local air was reported by only 15% in the Ship Channel but by 58% in the South-West.

Reported air pollution in the survey households thus corresponded with that measured by the monitoring machines. This represents a very important finding for three reasons. First, agreement between monitored and reported air pollution provides a strongly scientifically verified foundation to any conclusion drawn from the household survey as to air pollution and spatial variation. Second, the findings indicate that residents' reporting of air pollution is not only relevant but also balances and enriches the quantitative measures given in the air pollutants' reports. This fully justifies the quotation at the beginning of this chapter which highlights the opinion of residents. Hence, a fuller picture is obtained. As we shall see, local people's reporting, in contrast to monitoring reports, highlights the gravity of the problem by clearly describing direct effects of contamination and sharply addressing additional dimensions of environmental degradation and ill-health within the context of household location in relation to sources of industrial emission. Third, whilst all possibilities of examining aggregated government data had already been exhausted by the current research, there is considerable scope for further exploration of air pollution using information from the household survey, as the results of the current enquiry demonstrate. This way of acquiring knowledge is significant because it can improve correlations and provide the necessary elements to substantiate future policy regulations.

The next section moves on to analyze why people live in residential areas which are apparently recognized as having high levels of air pollution.

7.2.3 *Rationale for Residence in the Polluted Area*

Despite high concentrations of air pollution in the east side of the city, people live in the surroundings of the Ship Channel (see section 4.5.1). Substantial evidence in the literature shows that air polluted residential areas are usually occupied by lowest income populations (see sections 2.5.1 and 2.6.1). Most research on the relationship between environmental characteristics of living surroundings and social class can be summarised by 'where a household resides (and why it resides there) determines the extent to which risks associated with pollution will be experienced' (Murie, 1983, p. 16). The relationship between poverty and residence in contaminated urban areas was established in an interesting study in the UK, by employing three measures of 'environmental deprivation' (Townsend, 1988). Despite the fact that these categories hardly correspond with the same parameters with which the thesis is concerned, it is illustrative of the scope of environmental considerations. The categories were the size of the garden to which residents may or may not have access; whether there was a safe place for children to play; and whether the air in the neighbourhood was clean or dirty. It was found that the three selected indicators of environmental deficiency were highly correlated and that environmental deprivation tended to vary sharply with class. For example, children living in homes without sole use of a garden and lacking access to safe play areas near the home, were many times more likely to be living in polluted surroundings (Townsend 1979, pp. 532-538). In this literature, it is argued from both perspectives, in that areas of bad housing are often those which suffer from other adverse conditions, and that the highest levels of atmospheric pollution are found in areas with populations of low socio-economic status (Wood *et al.* in Murie, 1983).

However, the present research has shown that high socio-economic status households are also found in environmentally polluted areas. Therefore, it would be mistaken to assume from the outset that families live in the east side of the city because they cannot afford to live somewhere else, as implied in most of the literature. In Houston, low- and -high income households, whether knowingly or not, live in neighbourhoods with high levels of air pollution (see Plates 7.1 and 7.2). In the household survey in terms of broad social and economic characteristics, there is a considerable degree of heterogeneity among the populations in both sample areas (see section 6.2). It is the contention here therefore that traditional arguments, although fully valid, do not integrate the knowledge that certain pollutants expand beyond the proximity of their sources, are broadly dispersed in the air, and combine with other materials to form new pollutants; and that industrial development has occurred in previously populated areas (see section 4.5).

This situation therefore prompts the question of why people live in the polluted area in Houston. In terms of the number of households, 'closeness to work' emerged as the most important factor in the choice of residential area in both the polluted and the less polluted areas (33% and 38% respectively). 'Affordable rents' was the second most important reason for choosing where to live with little variation

Plate 7.1 A view that shows integration of expansive industrial development and housing in a low-income street in the Ship Channel area, indicating an evident source of urban contamination from nearby chemical plants.

Plate 7.2 Wealth and pollution share the east side of the city as can be seen in the affluent neighbourhoods of the Ship Channel area. The presence of newly built houses is not uncommon in the east side of the city near the petrochemical industry. Equally, well-endowed but old houses are found in residential areas of the Ship Channel exposing the prosperous but also historical character of settlement in this part of the city.

between the Ship Channel and the South-West (21% and 20%, poor and rich alike). However, in terms of the most influential factor differentiating between choice of residence in the east of Houston and the South-West, 'being local' appeared as the most significant (21% in the polluted Ship Channel compared to only 6% in the

South-West). To 'be local' meant that the respondent had always lived there, and that there was a feeling of belonging to the area. A final factor affecting decisions related to good 'reputation' of the area. 'Reputation' of the area was an important consideration for residents in Houston: good property value (e.g., house prices were slightly cheaper in the affluent residential Ship Channel than the affluent South-West), low crime rates, good schools, a friendly neighbourhood, all contributed to the reputation. Elkin *et al.* pointed out that 'nothing enhances a city's reputation more than friendly streets where there is plenty happening' (1991, p. 13). Focusing on high-income households, 44% of respondents in the Ship Channel and 64% in the South-West said that they lived there because of the good reputation of the area.

Old and low standard detached houses for rent or sale were available and affordable only in the east side of the city. To find cheap detached houses is almost unheard of in the South-West. In the east, the poor may also live in apartment complexes where rent is generally cheaper than in the South-West (see Plate 7.3).

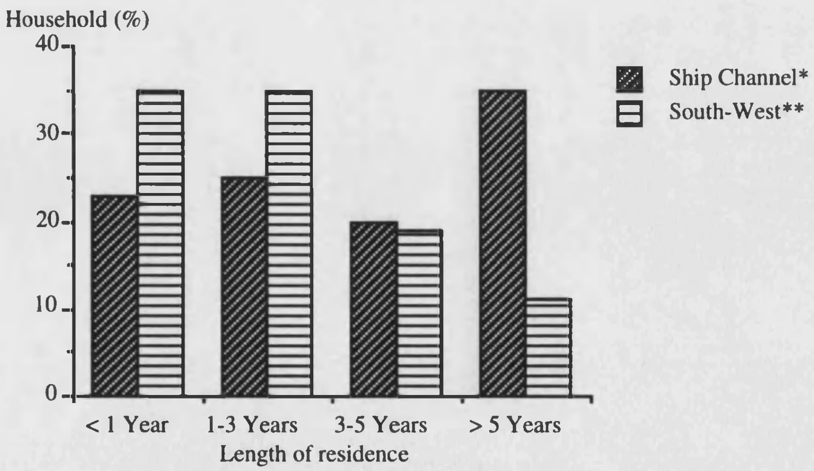
Plate 7.3 Many low-income residents live in apartments in the Ship Channel. Buildings usually date from the last twenty years and show less signs of vandalism as they do in the South-West study area.

The only housing facility in the South-West for low-income households is rented apartments. In the east side of the city, therefore, it was easier for the poor to find better housing conditions and have better value for rent money. However, the good reputation of the area was equally important for low-income households in the Ship Channel as in the South-West.

Furthermore, apart from wanting to live in the polluted area because it was close to work, rents were affordable and respondents were 'local', high-income households in the polluted and the less polluted area outlined the importance of kin and friendship networks (33% and 36% respectively). In summary, the reasons residents in the polluted and in the less polluted areas offered in terms of their choice of residential area did not vary significantly with the exception of 'being local'. These findings indicate once more that the east of Houston represents an old, well-established residential area (see section 4.5.1), that far from being inhabited principally by a poor population, it contains both those on low- and on high-incomes, and that the petrochemicals were only later comers. This is significant because it points to the fact that industrial growth happened with no real consideration for the effects that residents had to endure or for the tremendous damage caused to the environment.

This argument was confirmed by the length of time that residents had stayed in the polluted and in the less polluted areas. It was found that residents in the polluted Ship Channel settled in the area earlier and stayed longer than residents in the South-West (see Figure 7.2).

Figure 7.2 Period of time respondents lived in the same residential area, Houston, 1990



*Polluted area **Less Polluted area

Although the residential South-West has been more recently developed (since the 1940s), this was not the only reason. For example, 34% of all interviewed families in the Ship Channel had resided there for more than 5 years but only 11% had done so in the South-West. Length of residence for poor households also seemed more stable in the polluted area than in the less polluted area. Indeed, only 24% low-income households in the polluted, but 50% in the less polluted area lived in the surveyed address for less than 1 year. The same pattern was found among high-income households: 13% in the polluted and 21% in the less polluted residential area lived for less than 1 year in the same area.

Having established that 'being local' and 'good reputation' were crucial factors in the choice of residential location in the polluted area indicates that this part of the city was not any worse than any other (apart from industrial pollution). Perhaps, living in the east part of the city was considered a privilege because it has been settled earlier than the rest of Houston and it represents an old established neighbourhood. The length of time that residents lived in the same area, together with the reasons residents gave for choosing it, suggest that the population here was more established and equally attached to this part of the city. This, in turn, might have implications as to how residents considered the problem of local air pollution and of child ill-health.

In summary, the annual measures of air pollution in the east and South-West sites clearly indicated higher pollution in the Ship Channel area, notwithstanding remarkable ozone concentrations in the South-West. On the other hand, the degree of air pollution reported by residents agreed with the monitored pollution. These measures alone, however, were not sufficient to reflect the health impact on the population, if any. This was necessary in order to assess the contradictions of economic growth, in terms of localized environmental degradation and ill-health, and the economic and political structures. We move on to examine whether and how local air pollution affected the health of children.

7.3 Spatial Patterns of Pollution and Variations of Ill-Health

As discussed in Chapters 1 and 2, air pollution in cities has been responsible for various health problems and particularly, for rising respiratory child ill-health (e.g., Department of Health, 1995a; Dockery *et al.*, 1993, 1989, 1977; Schwartz *et al.*, 1991; Goren *et al.*, 1990; Villalbí *et al.*, 1984; Lunn, 1970). Selected pollutants have been identified as causing ill-health, i.e., PM-10, sulphur dioxide, nitrogen dioxide, ozone, and a mixture of air pollutants (e.g., PM-10: Ransom and Pope, 1992; Schwartz *et al.*, 1993; sulphur dioxide: Department of Health, 1995b; Bobak and Leon, 1992; nitrogen dioxide: Davies, 1994; Pönkä, 1991; ozone: Romieu *et al.*, 1993; Read and Read, 1991; and mixture: Department of Health, 1995b) (see Appendix D for detailed health effects of standard air pollutants).[1] The section examines how exposure to air pollution affects the health of children by focusing on three issues. First, the spatial patterns of illness and air pollution; second, reported immediate health changes triggered by rise in air pollution, and third, the length of local exposure to environmental conditions.

7.3.1 *Reported Long-Term Child Ill-Health*

The geographical distribution of reported child chronic ill-health problems reflects the impact of air pollution on the residential area. A distinctive spatial concentration of most recurrent child illness reported was found in the polluted area. Here, the prevalence of some conditions such as wheezy chest/asthma, stomach upset and coughs and colds was remarkably higher than in the less polluted residential area. The incidence of sinusitis and bronchitis was also higher in the Ship Channel than in

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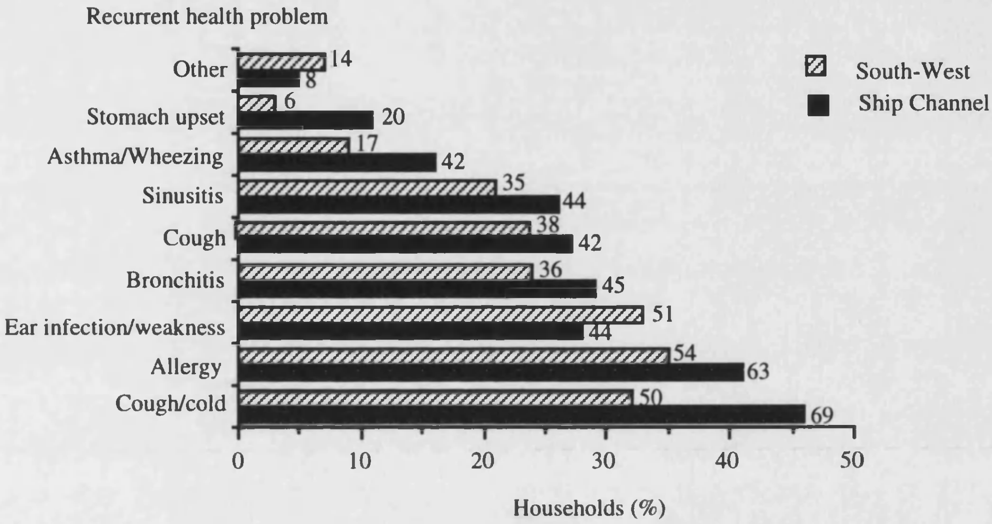
[1]Further recognized sources of ill-health are the carcinogenic Benzene, a VOC, which has become a well known health hazard (see section 4.3). It has been linked to elevated risk of contracting leukaemia (DoE, 1994; US EPA, 1990a). Furthermore, the risk of increased skin cancer has risen dramatically during the last 20 years. The damage to stratospheric ozone by exhaust and other ground toxic emissions has been pinpointed as a main source (Kripke, 1988, 1989; Sobel, 1979).

the South-West (see Figure 7.3). Therefore, a clear cluster of child ill-health, respiratory in particular, was identified in the residential area near the industrial sources of air pollution.

Figure 7.3 Spatial variation of recurrent child health problems, Houston, 1990



It should also be stressed that reported child ill-health was remarkably high in households far from the sources of industrial emission. This could be relatted to large concentration of reported child illness in low income households. Although the prevalence of illness in low-income households was not very different in the Ship Channel (72%) from the South-West (78%), poverty rather than local air pollution seems to be a more appropriate factor for ill-health in the South-West. The Urrutia Rojas study of the living conditions of the poorest population in the South-West has revealed a considerable incidence of respiratory diseases among these residents, lack of medical care, and high levels of unemployment (1988) (see sections 5.3.3 and 6.3.2). Thus, it is likely that economic and social disadvantages were major propagators of illness. However, this assumption does not invalidate the possibility that general level of background air pollution may also have been a trigger for ill-health in low-income households in the South-West.[2] Nonetheless, it is unlikely that

[2]It should be remembered that despite the fact that these households are located far from the sources of pollution, ozone pollution is also very high in this part of the city (see section 4.4.1).

it will be possible to assess the separate impact of either factor due to the strong influence of poverty in this area.

Particularly interesting is the prevalence of reported respiratory child illness in high-income households, because reporting here is less prone to the confounding effects of social disadvantage. In the Ship Channel, 23% more high-income households than in the South-West area reported child ill-health (72% and 49% respectively; n=75 each). Out of all reported cases of asthma and wheezy chest in high-income households (n=33), 70% were found in the polluted area. Furthermore, 76% of all bronchitis cases (n=2), 80% of children with stomach problems (n=5), and 62% of all children with chronic cough (n=32) were found in the polluted area. More high-income households in the polluted than in the less polluted area reported incidence of allergy (56%; n=43) and sinusitis (56%; n=26); these were also very high in the less polluted area (44% and 44% respectively). Only ear infection prevailed in the less polluted location to a greater extent than in the Ship Channel.

7.3.2 *Immediate Impact of Rising Air Pollution*

> ***I haven't noticed yet any change in my children's health but my two dogs get sick and weak every time we have the smell from the Channel (quotation from a mother in a low-income household in the polluted Ship Channel, Houston, 1990).***

Within the perspective of highlighting conditions that help to identify the adverse impact on people of air contaminants, the survey examined whether rising air pollution caused immediate health response and, if so, which type of reactions prevailed. It was thought that identification of health changes during and immediately after rise of pollution, had they occurred, would provide robust proof that particular causal mechanisms were activated. This indicator has not been investigated before in medical research nor registered in public health and air pollution control. This type of information could not be obtained from existent sources for two main reasons. First, epidemiological studies have been limited in their approach to this particular configuration of time and space. For example, studies have been done to compare daily levels of particular air pollutants with health reaction (Rutishauser *et al.*, 1990; Schwartz and Marcus, 1990; Stock *et al.*, 1988). These have used individual badges to measure exposure, or employed monitoring reports and spirometric tests to assess breathing changes. The problem with these techniques is first, that health changes are registered at a fixed time; second, they measure respiratory symptoms only, leaving out other health problems which may also be triggered by air pollution, e.g., headaches and eye soreness. Second, neither air pollution monitoring machines nor public health documents can describe how air pollution feels, what it does to children, or whether it has had an immediate effect on health.

The household survey was essential in procuring this information which was crucial for identifying the operation of biological mechanisms and social processes as defined in the causal model. The health effects of rising air pollution were examined in households which had been structurally and causally related, i.e., classified by similar socio-economic status, income and spatial location, with the purpose of explaining the distribution and the causes of the incidence of child ill-health (see section 3.4.3). In this sense, the intensive research approach to the households in the survey and the comparative analysis of the data convincingly complemented the analysis of government reports of air pollution and of public health status in Houston.

A fairly large number of interviewed households (41%; n=300) reported that any worsening of air pollution affected the health of their children. It is very likely that the reporting of health changes following rising air pollution would have been higher had it not been that a considerable percentage of households (24%) did not pay enough attention to rising air pollution and health changes. One third (34%) of the sample households did not notice visible health changes when air pollution rose. The most often reported health responses were allergy, headache, shortness of breath, and weakness together with eye soreness (see Table 7.2).

The risk from breathing polluted air evidently posed a health threat to Houston residents. It is more evidently so for residents, and for children in particular, who live in the proximity of the oil and petrochemical complexes and port facilities along the Ship Channel (see sections 4.2.1 and 4.4.1). The distribution of reported health responses to rising air pollution (n=123) followed a clear spatial pattern. The majority (64%) of reported reactions originated in the polluted area.

Table 7.2 Comparison of health changes following worsening air pollution, Houston 1990

Health change	*Reported complaints (100%)*	*Ship Channel polluted area (64%)*	*South-West less polluted area (36%*
Allergy	46	54%	46%
Headache	27	89%	11%
Shortness of breath	20	65%	35%
Weakness, eye soreness	18	72%	28%
Cough	10	30%	70%
Stomach upset	2	50%	50%

Focusing on the polluted area only, both low- and high-income households showed considerable awareness and concern for the health effects of deteriorating conditions of local air quality. Nonetheless, sensitivity towards air pollution and child health seemed to be more developed in high- than in low-income households (60% and 40% respectively). Mothers in low-income households in the polluted area tended also to attribute child health difficulties to a variety of reasons related to social inequality rather than to environmental conditions. While the relation sounds plausible, and the survey has shown significant correlation between poor income indicators and ill-health (see section 6.3), a significant fraction of child ill-health in low-income households, particularly in the polluted area, might have been triggered also by contaminated air.

In high-income households, on the other hand, reported health changes as a result of more air pollution were remarkably higher in the polluted than in the less polluted area. For example, every time that pollution levels rose in the Ship Channel over a quarter of children had headaches (26%) but only a fraction (4%) reported this in the South-West; well over a third (39%) developed weakness, uneasiness and eye soreness in the Ship Channel as did 17% in the South-West; 33% reported allergies in the polluted and 17% in the less polluted area, and finally, a rise in air pollution triggered coughs in 20% in the Ship Channel and none in the South-West.

7.3.3 *Effect of Length of Exposure on Ill-Health*

It was assumed that longer residence in the air polluted area would correspond with more reported child ill-health due to prolonged exposure to toxic air. While there are hardly any studies which either measure exposure to air pollution over an extended period (see Girt, 1972; Pope, 1989), examine the actual health changes, or estimate the cumulative risks of contracting ill-health as a result of prolonged exposure, there is some earlier evidence of suspected long-term effects of prolonged exposure to air pollutants (see Holland *et al.,* 1978; Bland *et al.,* 1974; Colley *et al.*, 1973).

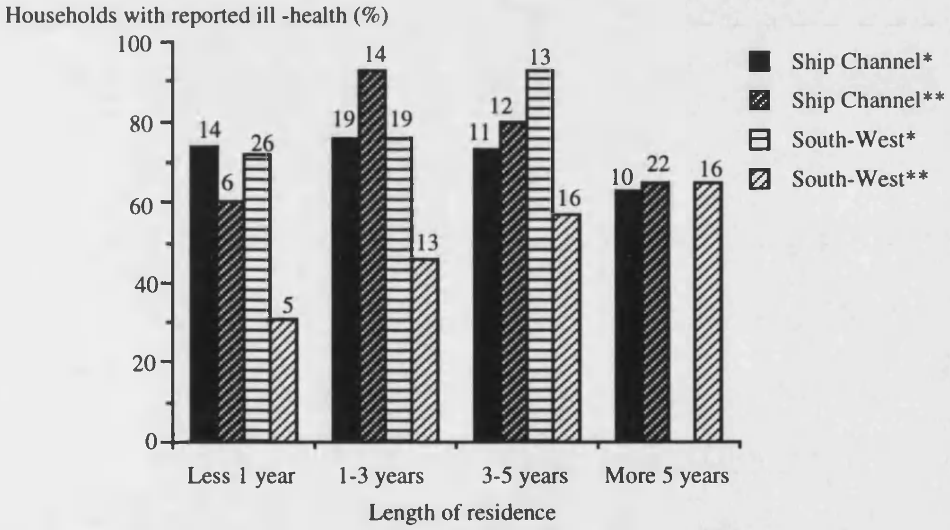
Residence at the same address or geographic area was classified in periods of less than 1 year, between 1 and 3 years, between 3 and 5 years, and more than 5 years. As established in section 7.2.3, residents in the polluted area had resided for considerably longer at the same address than residents in the less polluted area. It was found that in the Ship Channel the longer the family lived in the area, the higher the number of reported households with child ill-health. In the less polluted area, in contrast, highest incidence of child ill-health was correlated to shorter residence in the South-West (see Table 7.3).

Table 7.3 Spatial distribution of reported child ill-health according to length of exposure, Houston, 1990

Reported child ill-health	*Less than 1 year*	*Between 1-3 years*	*Between 3-5 years*	*More than 5 years*
Ship Channel	19%	31%	21%	30%
South-West	33%	34%	22%	12%

In the poor South-West, many more low-income households resided for shorter time at the same address (21%). Therefore, shorter stay and rising incidence of child ill-heath in the less polluted area was associated with poverty rather than with exposure to air pollution (see Figure 7.4).

Figure 7.4 Social and spatial variation of reported child ill-health by length of residence, Houston,1990



*Low-income households; ** high-income households

No clear pattern, however, has emerged between the length of exposure and child ill-health in low-income households in the polluted area. It is presumed that poverty may play a confounding and compouding role in the relationship air pollution and child ill-health. In high-income households, on the other hand, reported child ill-health persistently increased as exposure was more prolonged. Thus, the findings strongly support the argument that prolonged exposure to air pollution contributed to the deterioration of child health in the Ship Channel.

In summary, unpleasant and dangerous living conditions imposed by continual exposure to air pollution from the petrochemical plants is a feature of the Ship Channel residential areas. Health changes in children have been identified. Although contaminated air is also found in other parts of the city, i.e., the South-West, the degree of severity is undoubtedly worst in the area close to industrial sources of emission. Grave concern for children's well-being was vividly, and sharply, expressed by one local resident:

> *I do not want my children to grow up in this neighbourhood, although it is good and pretty. The refineries pollute the air. My neighbours are mostly widows, their husbands have all died from cancer. I do not want my children to live here (quotation from a parent in a high-income household in the Ship Channel, Houston 1990).*

7.4 Additional Sources of Environmental Hazard

The aim of this section is to examine children's possible exposure to two types of pollution and to highlight the limitations of accounting for individual, rather than collective, exposure as a main trigger of child ill-health in the presence of outdoor air pollution. First, exposure of parents to past and present occupational pollution is assessed. Since epidemiological studies have found associations between parental exposure to contaminating materials, such as radioactivity, and an increased risk of contracting cancer in their children (Hatch, 1992; Gardner, 1991; Gardner *et al.*, 1990), the possibility that the incidence of child ill-health in the surveyed households in Houston was correlated to parental occupational hazards is examined. Second, exposure to environmental tobacco smoke was assessed. Passive smoking has recently been acknowledged for its effect on respiratory problems, asthma and bronchitis in particular (Weitzman, 1990; Tager *et al.*, 1993; Martinez, 1988). Literature on the health effects of exposure to environmental tobacco is reviewed, and the dominant role of outdoor air pollution in the presence of passive smoking is thoroughly established.

7.4.1 *Parental Exposure to Occupational Environmental Hazard*

It was thought that earlier hazardous exposure of the mother might have affected the state of her children's health, or that pollutants may have been carried unnoticed by parents from work to home. Two categories of occupational exposure were identified, (i) past exposure to occupational or other sources of environmental pollution, and (ii) present exposure to occupational hazard of any member of the household. In both cases, the parents' reported previous and current exposure to environmental pollution was very small.

In the Ship Channel and the South-West, mothers had been equally exposed to toxic substances in the past. In fact, only 9 mothers in the polluted (n=150), and also 9 mothers in the less polluted area (n=150), reported that they had been directly exposed to pollution. Also, 19 mothers in each area did not know whether they had been exposed to contaminants. In spite of the fact that mothers in the two study areas had apparently been equally exposed to toxic substances in the past, child ill-health was still higher in the Ship Channel than in the South-West. The evidence clearly shows that it is very unlikely that mother's earlier exposure to toxic substances could have contributed to the extent of child ill-health found in the study areas.

Reported current exposure to occupational hazard was higher than exposure in the past, but still the frequencies were not sufficient to determine causal associations. More residents in the polluted than in the less polluted area were apparently exposed to occupational hazard. This might be so because one important reason for residents to live in the Ship Channel was proximity to work, i.e., in the petrochemical plants, refineries, in administration, and in other manufacturing facilities (see section 7.2.3). Exposure to hazardous substances at work was reported in 22% of the households in the polluted area (45% and 55% in low and high-income households respectively); and child ill-health was reported in 68% of these households (n=33). In the South-West, only 9% of the households had members who worked in hazardous environments; in 79% (n=14) of these households there was child ill-health. Child ill-health was reported in 60% in the polluted and in 80% in the less polluted area in low-income households of exposed parents. In high-income households, the incidence was 74% and 75% respectively. Neither household income nor geographical location added useful information to explain the relationship between air pollution and child ill-health of occupationally exposed parents. Undeniably, exposure to hazardous materials at work is the cause of numerous recognized diseases. Nonetheless, from the causal point of view, one must not allow the health risks associated with exposure to outdoor environmental pollution to be overridden by individual exposure, i.e., occupational exposure in this case.

7.4.2 *Passive Smoking and Child Ill-Health*

Child health has been employed as a main indicator for studies of the detrimental effects of exposure to tobacco smoke, i.e., passive smoking (see e.g., Forastieri *et al.*, 1992; Weitzman *et al.*, 1990; Hoppenbrouwers, 1990; Martinez *et al.*, 1988; Tager *et al.*, 1983). Although outdoor air pollution and environmental tobacco smoke may produce similar respiratory symptoms in children, the factors involved, and the character of the problem posed by each exposure is different. Nonetheless, at the political level, there has been a tendency to focus on the effects of tobacco smoke rather than on air pollution to explain increasing incidence of respiratory child ill-health. While not denying the devastating effects of tobacco smoke (e.g., lung cancer, heart disease, asthma, bronchitis, etc.), the thesis argues that a deliberate and narrow focus on tobacco smoke confuses causal processes. Therefore, the aim of the present section is to clarify the role of tobacco smoke in triggering ill-health and to discuss the role of passive smoking in the presence of outdoor air pollution.

According to the US EPA (1992), passive smoking is the unwanted exposure to tobacco smoke that occurs in various environments occupied by smokers: 'Exposure to tobacco smoke is dilute compared with mainstream smoke but it is chemically similar, containing many of the same carcinogenic and toxic agents' (ibid., pp. 1-2). In the USA, cigarette smoking is a major cause of mortality and morbidity. In Britain, it is the most significant behavioural cause of disease and premature death (Graham, 1990). There is increasing evidence to suggest that parental (especially maternal) smoking may be associated with an increased prevalence of respiratory symptoms and reduced levels of lung function in infants, toddlers and older children (US EPA, 1992; Weitzman *et al.*, 1990; Martinez *et al.*, 1988; Tager *et al.*, 1983). However, the possible role of parental smoking in inducing childhood asthma remains contested and not all studies have observed significant effects (US EPA, 1992).

The socio-economic circumstances of the household have also been considered as an 'effect modifier' in studies of parental smoking and respiratory status of children. Research of this type has revealed that smoking is a pattern of behaviour which, among both women and men, is associated with disadvantage.[3] Pierce *et al.* (1989) have observed that prevalence of smoking in women, and changes in this prevalence, were highly dependent on levels of education as this seemed to influence the effects of maternal smoking on their children's health. Martinez *et al.* (1992) found that maternal smoking had a much greater effect on asthma incidence in children of mothers with 12 or fewer years of formal education whereas maternal smoking by more educated mothers had no significant effect on the incidence of asthma among their children. In Britain, Blackburn and Graham (1992) found that a higher proportion of heavy smokers (51%) were in receipt of income support than those who had never smoked or ex-smokers (21%). In addition,

[3]By 1988, the proportion of smokers among women in the unskilled manual group (see section 6.4) in the UK (39%) was double that found among women in the professional group (17%) (Graham, 1990).

heavy smokers were more likely to be living in a household with no one in paid employment and with the proportion of women reporting debts rising steadily from 39% among those who had never smoked to 53% among heavy smokers.

Cigarette smoking is apparently part of a complex array of coping strategies for material, domestic and social difficulties. Smoking appears to provide a way of coping with the demand of full-time child care (heavy smokers are more likely than non-smokers to be living with more children in the household), with struggling to make ends meet, caring for someone with a long-term illness, with caring alone and with coping in unsuitable housing conditions (ibid.).

In summary, social inequality correlates strongly with heavier smoking. In low-income households, therefore, there would be more smoking mothers and it is more likely that more illness would be found among their children, with asthma and other illness of the respiratory tract being exacerbated. It should therefore be expected that the incidence of respiratory child ill-health will always be higher among children in the most disadvantaged households. While this is true - and this now becomes a crucial point - high incidence of respiratory and other illness has also been uncovered in high and middle income households in the city of Houston (APCHS, Houston, 1990; Chapter 6). This indicates that other precipitating factors, most likely of outdoor environmental origin, which are distributed spatially and are of structural character, have contributed actively to cause child ill-health.

7.4.3 *Simultaneous Exposure to Tobacco Smoke and Air Pollution*

The effects of outdoor air pollution have mostly been omitted in investigations of the effects of tobacco smoke on child health. A few key studies, however, have calculated the effect of side-stream cigarette smoke in the presence of air pollution. The evidence produced so far by these studies strongly suggests that in the presence of air pollution, passive smoking contributes only marginally to child health problems. It aggravates, but does not alter, the overall health outcome caused by the effects of toxic air.

A most authoritative study has revealed substantial evidence suggesting that, although cigarette smoking is strongly associated with mortality, estimates of pollution-related mortality are not significantly affected by the inclusion or exclusion of this variable (Dockery *et al.*, 1993). Furthermore, the risk of wheezing most days or nights was found to be twice as great among members of a non-smokers women's group all of whom had lived in a polluted area for a five-year period, as opposed to a less polluted area (Dockery *et al.*, 1989). Henry *et al.* (1991) found that, after controlling for parental smoking and other variables in the home, asthma was more common among children in Australian communities situated near major sources of air pollution. Equally, the prevalence among children of sore throats, evening coughing, coughs lasting more than 3 months, phlegm and wheezing was found to be significantly higher in a Hong Kong district where emission from factories reached higher levels, after adjustment for child smoking and exposure to parental smoking (Ong *et al.*, 1991). Forastieri *et al.* (1992) reported both, that exposure to passive smoking increased the already higher frequency of most respiratory outcome variables in school children living in two Italian polluted areas, compared with a non-polluted area, and that there would seem to be no synergism, that is no additional effects of the two exposures together. Similarly, in the Vaal Triangle, South Africa, where the levels of particulate matter were very high, Terblanche *et al.* (1992) found that 66% of the surveyed children suffered from upper respiratory tract illness (URI; e.g. sinusitis, rhinitis and hay fever) and 29% from lower respiratory tract illness (LRI; e.g., bronchitis, chronic cough and chronic chest illness). Slightly higher prevalence of LRI was reported in children exposed to parental smoking (26% versus 21% in households without parental smoking) but for children with URI, which was much more common than LRI, parental smoking did not affect the prevalence of infections.

The harm that tobacco smoke is believed to produce is mostly self-inflicted or side-stream.[4] Toxic emissions, on the other hand, may impair the health of the population indiscriminately. That exposure to tobacco smoke increases the risk of respiratory tract infections does not alter the need to examine environmental causes of ill-health, which surely relate to political and economic macro-structural factors (see section 2.8).

The frame of reference of tobacco and health studies is limited because it stops either at the individual or, at best, at the social class level of analysis. In this sense, politicians and scientists expect to find the source of causality and solutions to the problem of child respiratory ill-health in the individual rather than in the social and political structures of society. This parallels with the dominant approach in the natural sciences which ignores historical conditions of society which precondition events (see section 2.4). In this way, how society functions is usually unquestioned, and conditions which cause severe contamination are considered 'natural' and unavoidable. The unprecedented outbreak of asthma in London, in June 1994 illustrates this point (see section 2.2.2). Asthma is a disease associated with both exposure to tobacco smoke and with toxic emissions. But of course smoking did not rapidly rise, and then fall, over a 2 months period, when the asthma outbreak was registered. However, levels of atmospheric nitrogen dioxide and other pollutants certainly did. Thus it is important to investigate this phenomenon within a historical, political, and economic perspective rather than within the narrow frame of individual exposure.

There is, therefore, a strong case to conclude that in the presence of air pollution, passive smoking would contribute only laterally to child health problems, aggravating but not altering the overall health outcome caused by the effects of toxic

[4]Although exposure to tobacco smoke refers to individual behaviour, it should be mentioned that analysis of tobacco smoking should not be limited only to individual action. Rather, this should be understood in terms of socio-economic and political causes such as poverty (and hence the need to rely on an easily available support object), far reaching effects of advertising, the political and financial power of trans-national corporations, and taxation policy.

air. The historical circumstances that surround the events of ill-health are considered in order to produce a critical realist and political-economy explanation of the relationship between air pollution, ill-health and economic development. Smoking habits and exposure to tobacco smoke, and occupational exposure to environmental hazard, are thus only marginal factors in the political economy analysis of air pollution and child ill-health in Houston (see Plates 7.4 and 7.5).

Plate 7.4 A closer view at one section of the Ship Channel discloses the great density of establishements. More than 1,200 hazardous installations operate along the 25-miles channel. Their dangerous presence and massive release of toxic emissions reflect frenzied and uncontrolled industrial growth and full disregard for environmental and human consequences.

Figure 7.5 This view denotes houses with children whereby impressive petrochemical establishments outstand in the background. It illustrates a landscape of industrial and residential coincidence. Moreover, it depicts what cannot be directly observed: rampant economic growth, environmental pollution, and health hazard. It is the interaction of these components that this thesis has attempted to explain.

7.5 Conclusion

The central question which has driven this thesis is the identification of the underlying forces that promote environmental degradation and subsequent ill-health. It has been established that the level of child ill-health in Houston is well above what might be expected, but that the cause of this elevated incidence of ill-health is not attributable only to conditions of poverty in the household, individual exposure to such contaminants as tobacco smoke, or to a deficiency in the health care system, although this is seriously inadequate.

The research has distinguished between the socio-economic factors affecting the extent of child ill-health in practice, such as the role of income and parental structure, and the role of spatial contingencies derived from the location of the household in relation to industrial sources of air pollution. Chapter 7 demonstrates that the location of the household is a key factor for intensifying the risk of becoming affected by air pollution but that this general spatial conditioning forms part of the wider political and economic context for energy production and economic growth. The critical realist approach as established in Chapter 3, strongly shaped the analysis in Chapters 6 and 7 in the following way. It was clear from the beginning that the clues for causal associations would emerge from intensive and comparative, rather than extensive research and descriptive analysis because 'groupings of things simply by events do not show any correspondence between causality and event' (Pratt, 1994, p. 55).

The combined effect of social structures and biological systems to produce air pollution and ill-health has been most prominent in the Ship Channel area. Here, highly developed petrochemical establishments and other industries have grown continuously to the point where the city has won international recognition for its remarkable economic achievements but at the same time is confronted by severe ecological consequences.

CHAPTER EIGHT

CONCLUSION

8.1 Introduction

The objective of the final chapter is to bring together the main themes and issues that have arisen from this study, to analyze insights derived from the process of investigation, to discuss its limitations and to highlight practical implications for future environmental research. With this end in view, the chapter attempts to develop an approach that takes account both of the problems uncovered and conclusions reached in the foregoing sections.

8.2 Synthesis and Reconceptualization

This enquiry has examined the political and economic grounds for the current environmental degradation in the Houston area and has laid open the contradictory nature of capitalist economic growth in terms of the natural environment and human health. Economic growth over the last fifty years has conferred on Houston indisputable prestige and enormous wealth, but it has also condemned it to infernal levels of industrial toxic emission. High concentrations of air pollution and previously unnoticed clusters of environmentally related child ill-health found in the vicinities of petrochemical plants and, to a lesser degree, in households located far from the industries but also affected by these emissions, have attested to the repercussions of rampant and uncontrolled economic activity (APCHS, 1990, Chapters 6 and 7). The research also indicated an association between the extent of cancer death and its prevalent respiratory cause and exposure to Houston's massive industrialization.

Since the late 1940s, Houston has been home to one of the fastest-growing economies of the USA, and has particularly excelled in the oil business and international trade. These circumstances have been the result of interactively promulgated and structured vast industrialization, state and national environmental legislation that has been influenced by industrialists' requirements rather than by those of the city's inhabitants, and of the integration of the city as part of the international economy that underpins Houston's environmental crisis. An attractive business atmosphere has been ensured by the 'Houston growth coalition' and the involvement of the federal government which have both been crucial to recruiting generous federal funding needed to rehabilitate and expand the Houston Ship Channel, and to enhance the city's general infrastructure. These have contributed to sustain Houston's position as a corporate and subsidiary city within the international division of labour. It's economic success and continued population growth have awakened widespread admiration to the point that Houston has been dubbed 'the miracle city', 'the energy capital' and 'the pearl of the Sunbelt' (Chapter 4). This thesis' case study of Houston illustrates, however, that successful economic indicators necessarily hide unavoidable deleterious aspects of economic growth related to the natural environment. It also suggests that, where similar historical conditions dictate political and economic structures of unrestrained growth for profit like those in Houston, similar environmental degradation and ill-health should be expected to occur.

Houston is a city of conspicuous contrasts between wealth, professional excellence and hazards and poverty. In addition to outstanding industrial and business development, the medical industry has been widely recognized for its high standard; prominent Houston citizens are among the wealthiest in the USA; and Houston appears among the most technologically developed cities in the world as it features, for example, the NASA spaceship centre, unique modern heart transplant facilities, impressive skyscrapers surrounded by sophisticated motor-ways, and expensive residential neighbourhoods. However, the thesis has substantively indicated that access to proper medical care is reserved only for those who can pay dearly (as health care is almost entirely market-oriented), poverty is a widespread problem, particularly in Houston's inner city, and that water and air contamination are endemic problems that affect the entire population. In the light of surprising records of high infant mortality and a rate of cancer deaths which gives ample cause for concern, and of a remarkable number of days annually classified as health damaging according to the US safety standards (Chapters 4 and 5), the advantages of economic growth seem to be far outweighed by the disadvantages.

The city's apparent overall prosperity and continual promotion of economic growth have systematically obscured, in the eyes of researchers and politicians, the strong connection between capitalist growth and parallel environmental degradation. More significantly though, the drive for further capital accumulation has masked, the presence of children from clusters of low and high-income homes who suffer ill-health related to industrial pollution. Traditionally, higher risk of ill-health has been almost exclusively and narrowly attributed to sociological, individual or structural circumstances, e.g., to low social class, low household income, inadequate provision of health care, spatial exposure to hazard, and poor housing (Chapter 2). This research suggests however, that a household's circumstances, its geographical location, the members' exposure to environmental pollution, and the characteristics of institutional structures operate in conjunction with a particular political and economic system to cause ill-health within a particular historical setting. By continually emphasizing sustainability of economic growth and the control of emitted pollution and treating environmental degradation and capital accumulation as two separate entities, the understanding of the relationship between air pollution and child ill-health in major cities has been divorced from its political and economic origin.

Dangerous concentrations of ozone and sulphur dioxide, monitored since the early 1970s, have evidently become an accepted part of Houston's everyday life whereby different levels of contamination across the city cannot be dissociated from historical trends that have favoured industrialization as the necessary way for capital accumulation. The conjunction of Houston's economic and political structures and the historical circumstances that informed them, and the city's atmospheric conditions have contrived unique spatial configurations whereby industry and housing share nearby territory, and air pollution is integral to these areas. The prevalence of large amounts of industrial toxic emissions and their interaction with atmospheric conditions which favour displacement and the formation of new pollutants, means that the entire city has been dangerously exposed to various levels of industrial pollution. However, hazardous exposure is greater in the east.

The thesis has shown that a sudden change in the levels of pollutants appears to have acted as an environmental trigger for the reported incidence of short-term ill-health symptoms, i.e., headache, eye soreness, allergies, particularly among children who lived in the proximity of the Ship Channel area (Chapters 6 and 7). Furthermore, prolonged residence in air polluted areas has been associated with reported chronic health complaints, e.g., asthma, colds, bronchitis. Gigantic industrial and port developments have been prominently located in the east, as this side of the city is endowed with vital supplies of oil and gas, sulphur and water, and labour pools (Thomas and Murray, 1991). Oil-producing companies have continuously exploited these essential components of the industry, particularly so after the Second World War. The two banks of the Houston Ship Channel, the strait that extends from the Gulf of Mexico, crosses the ring-road 610 Loop and penetrates far into the city, displays densely industrially developed land. The thesis has indicated the major threat posed to the environment and to human well-being by the presence of enormous tanks of gas, petrol and other combustible materials, which have been dangerously erected close to major population centres, and the danger from the operation of numerous petroleum establishments and excavation towers.

The analysis of the empirical information obtained from the survey conducted in two areas within Houston has exposed the importance of the geographical location of the house in relation to industrial sources of air pollution. This information has been essential to highlight the empirical and political significance of localized environmental degradation and to identify hazardous consequences of economic structures. Whilst theoretical analysis has stressed the relevance of historical processes of capital accumulation to understand Houston's structural and environmental reality, the nature of the empirical results suggests a strong connection between spatialized ecological and health changes, and current economic and regulatory contexts of the city. Significantly, a growing number of residents gave expression to the implication of a long history of rampant economic growth, particularly in the oil sector, voicing their anxieties at the severe pollution, and stating their opposition to continued growth on the same environmentally inconsiderate lines (Chapter 4).

In this conclusion every attempt has been made to link arguments and findings in one substantial and comprehensive text that reflects the conceptual foundations that have driven this thesis, i.e., the interaction between apparently opposing factors, combination of analytical levels, the integration of spatial and social variations of pollution and ill-health with economic structures, and the adoption of a historical and political-economy perspective. The interrelations carry most weight in explanatory terms and these have been one main focus of this thesis. To define basic linkages was problematic - but essential - and, not surprisingly, has rarely been undertaken by other researchers. The air pollution and child ill-health question emerges from this thesis as complex, structural and multi-faceted. However, if an explanation of the relationship between current environmental degradation and society is to have a clarifying purpose for other researchers and, not least, to indicate a political direction for radical change of environmental control and economic policy, explanation should be clear and explicit. This is not, however, an easy task. Only by deconstructing the discourse surrounding environmental degradation can we reconceptualize the foundations of the relationship between air pollution and child ill-health. The thesis suggests a dynamic, political-economy model, as opposed to a static model, for the explanation of this relationship.

A number of interrelated themes have formed the basis for the exploration of the questions addressed in Chapter 1: the implication of economic activity; the role of the international economy; the role of federal and state air pollution regulation; the relevance of the health care system; the nature of air pollution and of environmental ill-health; the role of household socio-economic and demographic composition, the importance of household geographical location; and the character of hazardous exposure. Drawing on the analysis of the above components in conjunction with the theoretical conceptualization that this thesis has adopted, the findings of this research can be discussed under three broad themes, as follows.

8.2.1 *Method and Political-Economy of Air Pollution and Child Ill-Health*

The contradictions of economic growth in terms of air pollution and child health in Houston were difficult to predict using the available information and employing traditional methods of research. Spatial and socio-economic patterns of air pollution and ill-health are certainly important in their own right because they may specify the extent of the incidence and particular characteristics of the relationship. However, these are more important for what they do not directly show, i.e., the involvement of social processes which are responsible for ecological and health changes. Previous works have approached air pollution, ill-health and the economy almost exclusively from pragmatic and structuralist positions, particularly in the disciplines of epidemiology, geography and sociology, or else, from a theoretical standpoint within environmental economy. Viewed from these perspectives, the potential risk of hazardous exposure has been reserved either for the poorest (but with some exceptions such as the risk of child leukaemia from nuclear pollution) or, particularly, for those who live down wind of pollution.

The thesis' theoretical analysis has argued that the operative power of macro-economic structures which historically seek to reproduce capital accumulation, has been evident within the character of US national and the city of Houston's economic policies; these have promoted intense industrialization and urbanization, complete internationalization of the energy sector, and concomitantly, have advanced local environmental degradation in Houston. However, at the empirical level, while interaction between ecological and economic events seemed to affect all Houston areas and residents equally, the implications for them were substantially different, depending on the location of the household in relation to sources of industrial pollution. Spatial variation of air pollution and of child ill-health in practice offered key indications of political and economic structural processes which have constructed spatialized differentiated environmental conditions, and these, in turn, have significantly altered the ecological aspect of living conditions.

The analysis of economic structures and regulatory institutions in Houston in conjunction with a theoretical analysis of dominant historical processes could not predict whether, how and where air pollution affected the population. The thesis has indicated unexpectedly high levels of air pollution, infant mortality, and cancer death in Houston, as witnessed by analysis of monitoring reports by the city, state and national air pollution control agencies and assessment of the city's public health statistics (Chapters 4 and 5). However, because of the aggregated character of these contextual data, notwithstanding their initial utility, no specific information could be obtained as to who the diseased were and where they lived. Therefore, one main benefit of having surveyed the population was the acquisition of information that was impossible to access otherwise but which was essential to produce an explanation, because levels of air pollution and variation of child ill-health constituted the key link between political and economic structures, ecological change and socio-economic factors. In addition to providing a window on the working of historical processes, the combined study of environmental and health changes over space and household social circumstances is a useful research approach. It encapsulates biological, political and economic dimensions, allows concrete examination of hazardous conditions and assessment of the state of child health, and permits identification of interconnecting relations among these factors. Hitherto, these foci have been consistently separated in scientific research.

The study of Houston uncovered a high incidence of child ill-health in the sample households in general; moreover, as expected, the incidence of illness among poor children was always very high, indicating that social inequality made children more vulnerable to disease. However, socio-economic circumstances in the household were not sufficient to justify the reported incidence of child ill-health. Importantly, the incidence of reported child ill-health was unusually high in wealthiest households in the air polluted Ship Channel. Sociological arguments that claim causal exclusivity of poverty for ill-health should consequently be challenged. In contrast to previous research, a most illuminating finding in the household survey was the extensive incidence of reported child ill-health in high-, rather than in low-, income households. The survey's results indicated that spatial factors, which had been structurally conceived, rather than individual and sociological circumstances, were definitively influential in the relationship and crucial for its understanding (Chapter 6).

The thesis claims that environmental degradation and hazardous exposure are always expressed in a spatialized manner (Chapter 2). Comparative analysis of the levels of reported ill-health by household in previously defined socio-economic and environmental contexts was the key strategy to elucidate the origin of high incidence of child ill-health in the surveyed areas within Houston. Physical proximity has emerged as an important factor because it has pointed to the presence of processes that underpin rising ill-health and air pollution. A main issue to come out from the thesis is the importance of political and economic analysis of spatial variation of both household location and levels of air pollution. It casts significant light on the cause of so much ill-health found in the survey because geographical location was crucial to relate industrial growth and excessive pollution whilst exposure to air pollution was highly associated with the health of local children. It seems appropriate to infer that the incidence of chronic child ill-health, particularly in wealthy and poor households in the Ship Channel, and to a lesser degree in the South-West, has been strongly modified, but more likely, caused, by persistent exposure to environmental pollution which is the outcome of an extended historical economic process of chemical industrialization in the Houston region. Significantly, though, if an analysis of environment and society is to address the combined effects of social and locational circumstances, the spatial form should be interpreted in terms of social construction and of related environmental quality and understood as a combined economic and ecological structure of potential risk. This is a key reconceptualization of geographical location which reveals the far reaching interaction between ecological mechanisms and social structures of economic growth, and which points at the unwanted, but most likely, pollution and ill-health consequences.

Spatial variation of child ill-health and air pollution is a good example of the way in which equal historical processes can produce different empirical events, but it also indicates that embedded variation cannot alter basic trends of capital accumulation which have unleashed hazardous environmental conditions. The empirical research recorded in previous chapters shows quite clearly that economic and political structures, and historical processes, produce concrete forms of growth and degradation over space, and that variation of child ill-health has indicated that children in households located in the proximity of the massively industrially developed Ship Channel were more directly affected while others did not suffer equally or were not affected at all. However, and a crucial conclusion of the thesis, recognition that greater and lesser levels of pollution and of ill-health coexist within the same social and economic structures should not be interpreted in any way as endorsing present economic structures which perpetrate localized and variable degrees of damage. Equally, the fact that children are differently affected by air pollution (an outcome which this depends on structural location and social exposure) should not be interpreted as if neutralizing the contradictions of economic growth, because the origin of ill-health and its degrees of severity rely on the organization of society and its mode of production which promote prosperity for the few and misery for many.

The evidence that emerged from comparing case studies within Houston suggested that reported chronic child ill-health, which was mainly of respiratory origin, was associated to a remarkable extent with both the level of reported and also measured pollution and that this was worst in the Ship Channel area (Chapter 7). The city's public health documents were severely deficient in providing this type of vital information. The longer children had resided in the same area, i.e., in the Ship Channel area, the more ill-health was reported by the household. The length of exposure to industrial air pollution was a definitive indication. Short-term, as opposed to chronic, reported symptoms - and those which were not only respiratory, e.g., headache, allergies and eye soreness - were again significantly associated with reported rising levels of air pollution, a phenomenon more often registered in the Ship Channel. This information was made available because residents were surveyed in the exposed areas, i.e., within their 'causal' and structural contexts, a procedure which illustrated the usefulness of comparative study within an extensive and intensive research design. Residents' interviewing through household surveys has the potential to capture the 'combination' effect of structural and spatial factors and the uniqueness of the events.

In addition to the fact that certain pollutants are known to be ubiquitous, lower levels of air pollution seem to represent a considerable problem, as testified by moderate incidence of reported environmentally related child ill-health in the less polluted South-West area (Chapter 6). The conclusion drawn is that present US pollutants safety standards (Chapter 4) seem inadequate to protect Houston's residents' health both in the short and in the long term. This argument is strongly supported by numerous more extensive epidemiological studies which have attested the detrimental health effects of lower concentrations of pollutants in major cities (Chapter 2), by the high number of days with PSI < 100 in Houston, but which were yet outside the very hazardous category (Chapter 4), and significantly, by evidence of the association found in the household questionnaire which highlights the health effects of both high and lower levels of ozone and sulphur dioxide (Chapter 7).

The addition of additional factors that focus on the individual, such as occupational exposure or tobacco smoking, is practically irrelevant in the presence of the powerful effect of outdoor industrial pollution. They cannot alter or invalidate the fact that air pollution is a direct and pervasive trigger of ill-health in Houston (Chapter 7). Limitations in explanations of this type are rooted in conceptual restrictions in the natural and social sciences which address the subject as a physical, or alternatively, as an exclusively sociological, phenomenon, disregarding interrelationships among historical specifics, structural factors, and empirical variation. Individual rather than collective exposure has been the focus of these approaches, and the political implication is one of avoiding social responsibility for ill-health.

Examination of the spatial patterns of air pollution and child ill-health in an historical, political-economy light exposes the social importance of health issues usually underestimated in the environmental agenda (Chapters 1 and 3). The relationship between ill-health and environmental pollution needs to be understood neither as purely biological, exclusively sociological, nor solely structuralist. It is a political relationship composed of those dimensions. The combined effects of biological, socio-economic and political circumstances and must be interpreted within a framework of spatial potential risk due to the social construction of widespread areas of environmental degradation. If this epistemological change affects the course of research, it will contribute to challenge fundamental atomist, dualist and reductionist assumptions in scientific thought. It follows that the recognition of the interrelationship among political, economic and ecological events indicates that neither the social nor the natural sciences with their present epistemological foundations and research methods may be sufficient or competent enough to explain the problem, let alone to resolve it (see, for example, Benton, 1994; Yearley, 1994, 1991; Oakley, 1992; Dickens, 1992; Redclift, 1984).

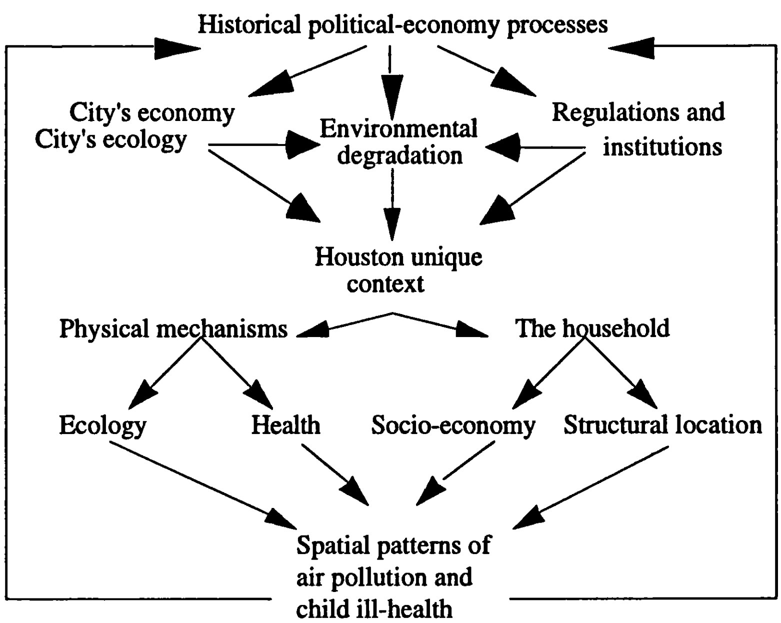
In summary, the thesis has suggested a political and economic perspective and a combined method to approach and explain an apparently only medico-ecological situation.

8.2.2 *Conjunction of Nature and Society*

A main challenge for this study has been to overcome one of the most fundamental assumptions of scientific research, that events are ahistorical and unrelated. Significantly, the Houston study is an attempt to begin to address the lack of adequate research on empirical aspects of environment and society problems and to frame them within a historical perspective and political and economic context. The thesis does not deny that increasing environmental degradation and ill-health are physical and empirical phenomena but it suggests that these are clearly mediated by society. The biomedical sciences have explained the relationship between air pollution and child ill-health in major cities. As discussed in Chapter 2, this is misleading because the nature of any real situation is a combination of several structures of relations which operates in open systems where structures overlap with each other and with contingent factors (Sarre, 1987). An explanation of the relationship between air pollution and child ill-health in Houston has been built upon the thesis alternative claim that environmental degradation and ill-health are physical reactions to socially abused biological systems (human and ecological).

The conceptual basis of the thesis has argued that ecological mechanisms are very important because they determine the capacity of the environment to absorb human pollution, to regenerate itself and to disrupt the atmospheric chemical balance. However, any precipitation of an ecological episode in modern cities takes place under socially constructed contexts and therefore occurs because factors other than the physical activate a pollution reaction. Indeed, the existence of remarkable levels of industrial air pollution in Houston has necessarily presupposed the development of industrial plants. Industrialization, population growth and internationalization of the economy have been contingent upon necessary social relations which by necessity employ generative mechanisms to produce and reproduce capital accumulation. But, unregulated and extensive development of the energy industry in the region has been a concrete and crucial element in the generation of economic growth and practical degradation of the local environment. The thesis suggests that to pinpoint industrialization as the ultimate cause of excessive contamination is misleading because it ignores complex capitalist social relations, that capitalist processes and relations of production are at the core of industrialization and have heavily shaped environmental legislation (e.g., Porrit, 1984; Illich, 1975; Chapter 2). However, the unique historical context that has given rise to air pollution in Houston should be illuminated by empirical analysis which acknowledges the extent of ill-health and variations within the same city and assesses the effect of social structures and ecological mechanisms responsible for changes (see Figure 8.1).

Figure 8.1 The relationship between air pollution, social structures and child ill-health



Despite the unique characteristics of the environmental crisis in Houston, its causes should not be sought only within the boundaries of the city. Neither can its solution be a matter of local politics alone as similar environmental crises have taken place in Paris, London, Mexico City, Los Angeles and Houston and pollution in the 1990s resembles that which provoked infamous episodes in the 1950s (Chapter 2). In fact, the introduction of US national pollutant standards and state control of industrial emissions at source (Chapter 5) were not intended to conflict with political priorities for economic growth even if growth was known to cause further adverse environmental damage. The input of the state in regulating the environment and protecting public health in Houston has not significantly contributed to stop or reduce air pollution nor to slow down the construction of new industrial plants. If we appreciate that the local environmental crisis in Houston is historically determined with the activities of multinational organizations and national governments underlying environmental and economic changes, future research will be in a position to dispute the relative role of the state and to challenge the present narrow views. These misguidedly maintain that local government alone will be able to improve the quality of life of residents just by providing localized environmental protection and better health care to its most vulnerable inhabitants (notwithstanding that these are certainly needed).

The analysis used in the thesis has demonstrated that the value of the political-economy approach to explain environmental problems is that the wider historical and economic context of physical and social change is thus examined. Following this line of thought, ecological problems should not be understood as mere functions of sociological rationale alone, an assumption which reduces environment and society research in major cities to the obvious statement that the poor live in the most polluted areas (Chapters 2 and 6). The underlying causes of rising air pollution in Houston, and of subsequent related ill-health, are political and economic, and the main forces that have instigated them have been effectively masked by an exclusively biological focus, or a weak regulatory approach. This interpretation has neglected both wider political and economic contextual factors and the interaction between seemingly opposed social and physical systems.

The results of this research suggest that 'capitalist development transforms nature and the environment within a logic which needs to be understood in global terms, and which has characteristics today which it did not possess 50 or 100 years ago' (Redclift, 1987, p. 47). Houston illustrates such transformations. The city became an international haven for profitable economic activities whilst the Houston Ship Channel area in particular was transformed into a haven of energy-related activities. Together with economic transformations, environmental degradation built up constituting a localized pollution hell. Therefore, contextualization of environmental local changes in Houston within the framework of the international economy is vital.

The conjuncture of environmental and societal dimensions must be situated within the context of economic growth and local environmental degradation and can be considered in relation to the debate on the current internationalization of cities and the process of economic globalization (e.g., Keil, 1995; Sklair, 1994; King, 1991; Sassen, 1991; Giddens, 1990; Feagin, 1988). Certainly, Houston was a highly economically developed city before the expansion of the energy sector and environmental pollution was certainly known. However, the ecological disruption that the petrochemical industry and general economic growth brought into the region since the early 1900s and after Second World War in particular, has been radically different and many times more severe.

The thesis suggests a reconceptualization of the relationship between air pollution and ill-health in Houston which favours an interaction of several categories of relations while acknowledging the integral role of historical social processes and the part of the state and legislation. A combination of analyses according to fundaments of critical realism but including the lessons learnt from sociological, biological, geographical and green economics theories (Chapter 2) may satisfactorily explain the relationship.

8.2.3 *Critical Realism and Dynamic Explanation*

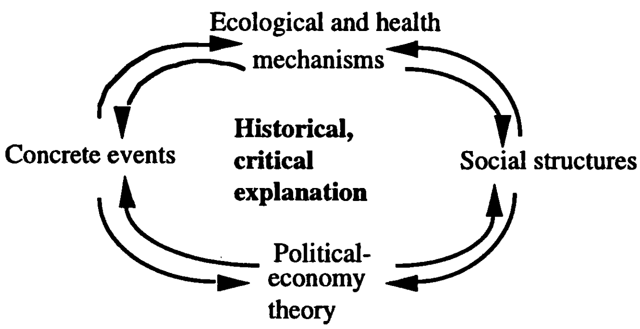
Because substantive research results, and how they are used by others, depend partly upon the methods and aims of explanation used by the researchers (Dickens *et al.*, 1985), these conclusions also draw on particular critical realist tools and on aspects of the methodology that needed to be explored further to reveal their relevance for the present research. Critical realism helped the researcher to view environmental degradation and ill-health in a socially enriched light.

One conclusion to be drawn from the Houston case study is that a key point in carrying out historically informed environmental research of the population is the selection of adequate empirical case studies, the grouping of households with shared structural characteristics, the type of questions asked in the survey, and the comparative design of the investigation. The thesis suggests that rather than competing with each other, intensive and extensive research designs can be tailored to suit the needs of the investigation and that necessary relations can be discovered in a large but properly distinguishable number of cases without affecting the quality or explanatory power of the findings. Parity of extensive and intensive research design with quantitative and qualitative analyses may actually narrow the possibilities for acquiring further knowledge. More than anything else, what gives the researcher an indication of deep relations between social and environmental structures is the proper identification of the population according to relevant categories, enabling differences and similarities to be compared in their causal contexts.

Quantitative analysis of all the interviews with Houston residents, but without classifying that population by sub-groups, was necessary to determine the extent of the problem of child ill-health in Houston because this was not previously known (see Chapter 3). Significantly, however, the deeper analysis of the information obtained in this way proceeded on the grounds of a strict categorization of the surveyed households by their socio-economic conditions and the location of the household, i.e., in relation to structurally constructed spaces of higher air pollution. These represented essential elements for assessing variation in context, to calculate the extent of personal risk, and to indicate strong relations of association. Whilst quantitative analysis of aggregated data was necessary to appreciate the magnitude of the problem, it was definitively not sufficient to indicate why it was happening (see Figure 8.1). Comparison of effects by the socio-economic condition and geographical location of the household was the key research criterion to identify relevant associations which pointed at the involvement of physical mechanisms and relevant social structures. It is argued that in environmental and social research, quantitative, comparative and contextual analyses should complement each other so that the benefits of descriptive generalizations, the clarity of correlations and the depth of empirical associations can be fully integrated.

The thesis concludes that the structure of explanation of spatial and historical patterns of environmental degradation, remarkable extent of child ill-health and massive and prolonged economic growth in Houston cannot follow a static model because the events are the outcome of ongoing interactions (see Figure 8.2).

Figure 8.2 Dynamic relationship among components of explanation



The relationship between air pollution and ill-health must be seen as cumulative rather than single-stranded, as determined by political and economic as much as by biological circumstances, and as retroductive rather than final. Paradoxically, it is exactly the arduous process of deconstructing the taken-for-granted assumptions surrounding the question of environment and society, and of breaking them down into constitutive parts but incorporating new, improved postulates in a dynamic structure which, in turn, makes explanation possible and the environmental problem comprehensible and accessible.

An appropriate explanation of the relationship between air pollution and child ill-health must reflect the interactive nature of its components and express a critical reconceptualized vision. At the same time, it must highlight the dynamic character of the explanation. Under these terms, an explanation of environment and society which is political and economic but also biological is more reliable because it embraces the dynamism and complexity of the real world within an ordered and conceptually informed framework. Linking conceptual and empirical information and generating critical theory is something that can be achieved with critical realism. Critical realism 'offers a guide to the practice of research and theory generation, both of which are inter-related. Theorization is a mode of explanation; not an end in itself' (Pratt, 1994, p. 204). A re-conceptualization of the relations between the economy and environmental degradation is thus called for. The relationship can best be seen not only as biological but, primarily, as historical and political.

In conclusion, this methodology is not a cure for the generalized limitations of environmental research. The thesis' approach does, however, represent an opportunity to contribute to a deeper understanding of the relationship between environment and society, particularly in respect of those concerns relating to environmental impacts and hence health effects of policies of economic growth.

8.3 Avenues for Future Research

The following section will discuss some issues arising directly from the present research and which demand greater attention because they raise certain questions not addressed in this study, but which could fruitfully be explored. Given constraints of time and feasibility, the study was not able to cover four important and related areas of analysis. The researcher strongly feels, however, that any information elicited would not have altered the conclusions of this thesis.

First, the focus on one city was very important because the investigation could concentrate on many aspects and changes taking place in Houston. In addition, Houston was not seen in isolation but was firmly contextualized in the national and international economy and thoroughly identified in the subsidiary and functional and economic role that the city has fulfilled. Houston provides an example, rather than an exception, of a highly economically successful US city that developed under the umbrella of federal funding, through international connections, the presence of multinationals, and the ability of the local economic elite to promote massive unregulated growth (Chapters 3 and 4). Without doubt, economic success coupled with remarkable advances in the medical science and within a highly developed medical care sector (Chapter 5) have enabled the cure of previously untreatable conditions (e.g. health disease by heart transplant), and extended overall longevity. Population growth, new sources of employment and a heavily promoted business atmosphere have brought exceptionally high incomes for a section of Houston's population. However, it is evident that increase in material wealth in these societies, and in Houston in particular, reflects one side of economic growth; severe air contamination, increased exposure to environmental hazards and pronounced health and social inequalities comprise the other. These particular contradictions of economic growth were the core subject of my study which has addressed them by focusing on the role of three social structures - those responsible for economic activity, environmental legislation, and health care provision - for their crucial effect on the well-being of the Houston population and for reflecting the working of a capitalist social system. This thesis has criticized the disregard of those responsible while highlighting both the inadequacy of the health system's delivery and flaws in the regulatory mechanisms for toxic emission control.

In order to examine further the assumptions made here on the influence of historical social processes and the concrete role of political and economic structures on the phenomena of environmental degradation and ill-health in cities, the thesis' research design could well be developed in the following way. By comparing same parameters in two cities rather than in one, this investigation could benefit from a larger scale study, since a comparison in these terms might be instructive. It would be necessary to present a complete panorama of air pollution and related health parameters in the selected cities from a historical perspective as well as detailing the current state of affairs and identifying common factors. Comparing two cities is likely to provide relevant insight into different outcomes resulting from the working of similar political and economic structures. It will encourage, in the light of different contexts and findings, the expansion of the analysis presented in the thesis on the interconnection between economic growth, air pollution and ill-health. Although research along these lines may forego some of the depth of a single-city case study, there would be plenty of scope for comparing connections between air pollution, child ill-health and economic growth within and between different cities.

Second, the wide scope of the research subject and a fragmentation in the literature made the investigation remarkably difficult. Despite the omission of certain debates and considering the breadth of the theoretical chapter, the analysis has not lost any of its depth, a depth achieved thanks to the insights derived from existent knowledge in the disciplines of green economics, sociology, geography, epidemiology and biology. Due to constraints of time and space a detailed debate on industrialism in the political economy section was not attempted; further research might possibly address this. The discussion here, limited to only the most representative branches and authors of the approach, leaves room for a more detailed account of these approaches. The same critique applies to the debate on sustainable cities.

Further exploration of the debate on industrialism may benefit from the examination of the following issues: the extent to which ecological modernization still relies heavily on technocratic solutions to ameliorate pollution problems; its poor treatment of the distribution of social benefits and environmental risks that result from industrialization; and, lastly, the ways in which this literature interprets the valid claims that industrial processes unavoidably disrupt the natural environment. The thesis emphasized, however, that while identifying the effects of industrial development on the environment and human health is crucial, it is insufficient for an understanding of severe environmental degradation and the links to economic growth. Research might usefully encompass the historical social relations that have generated industrialization. Moreover, while acknowledging the powerful role of current and past industrialization in modern society, industrial development must be seen as only one of powerful capitalist strategies to accumulate and reproduce capital (Chapter 2). Indeed, the relationship between economic growth, air pollution and ill-health is complex and contradictory.

Without doubt, since the early 1950s, several aspects of society have been improved remarkably as a result of growth and internationalization of the economy. Wealth acquired in this way has promoted research which has resulted in the reduction of infectious disease, longer life expectancy and abundant food supplies - some of the most striking changes in relation to pre-industrial times. I argue, however, that the capitalist framework of economic growth also determines a strong polarization as to who can benefit from undeniable improvements and who is most exposed to its visible and invisible deleterious side effects. Patterns of spatial variations of air pollution, child ill-health and industrial settlement have been seen here as essential indicators of the interrelationship between economic growth, environmental degradation and deterioration in the state of child health. My point here is that, underlying some incontestable and useful changes, economic growth hides a substantial potential for ecological misery. The thesis has attempted to deal with these particular contradictions of economic growth. A clear conceptual model featuring the most relevant aspects of the theoretical approaches, but one which is unique and unified under a political-economy perspective was designed and followed in the thesis' analysis (Chapter 2). Clearly, the work in the thesis is far from comprehensive; but it has, at least, identified avenues for further investigation that may continue to throw light on this subject.

Third, the survey has provided a rich source of information on the state of child health in a large number of households in one city, Houston. Conducted in two geographical areas within Houston, the household survey was used to obtain a deeper insight than that gleaned from the city's air pollution and public health reports and to substantiate the literature of Houston's past and present environmental degradation and economic development. The comparative research carried out of households in two areas within one city has revealed crucial coincidence of events, i.e., a higher than expected level of reported child illness, high levels of monitored reported and measured air pollution, and the location of the house in relation to sources of industrial pollution. These findings were contextualized and associations deduced. A detailed study of households in two areas subject to different degrees of pollution substantively complemented the theoretical and contextual examination of the single-city case study.

Survey data are important because these indicate trends that could not be known otherwise. However, it is necessary to stress that information so obtained may not be fully accurate and representative due to constraints both of cost and time, as well as the inevitable problems inherent in the interview process. There are, thus, problems in conducting surveys in this way; for example, surveys are time and space specific and therefore cannot incorporate later changes. Other common problems relate to the introduction of leading questions, charges of implicit bias, and difficulties of accurate reporting. Also, such characteristics as gender, age, social status, race and ethnicity of the researcher create an immediate impression of the interviewer and will, in part, place limits on the roles that interviewer may adopt (cf Appendix A.5 below; Burgess, 1991).

From the outset, I intended that respondents should know that the aim of the survey was to collect information about local air pollution and child health despite the possibility that this knowledge might have coloured the respondents' answers. However, I assured interviewees that all information provided was confidential and explained clearly the purpose of my study in Houston. Furthermore, in order to avoid some of the above-mentioned problems, questions relating to local pollution were neither asked at the beginning of the questionnaire nor grouped under specific sections. Instead, these were presented randomly and mixed in with socio-economic and state of health questions. On the other hand, the comparative design of the survey, with study and control case studies, was useful in dealing with problems of over- and under-reporting, and therefore in improving the accuracy of the findings. It was also important to ensure a large number of cases, 300 in total, for meaningful subgroup analysis. I tried to overcome the problems of reporting bias and the possibility that residents would use the questionnaire as their vote against local pollution by asking the same questions to populations of different socio-economic status and who lived in areas with different degrees of air contamination. I appreciate, nonetheless, that despite incorporating various strategies to overcome with these obstacles, the very nature of surveys determines that it is unlikely that all difficulties will ever been completely removed. However, it is necessary to stress that survey data are not sought for the purpose of explaining anything but rather to reveal trends which then need to be adequately deciphered with the help of complementary analytical methods.

The combination of a large and representative number of cases for the survey, the comparative method adopted and contextualization of the findings has necessarily enhanced the scale and depth of this enquiry. A few semi-structured interviews with key people in Houston complemented the investigation. While not the core of this research, views, information and insights given by informants during such semi-structured interviews have been quoted and used to reinforce arguments. There is scope for conducting many more such interviews, and also for carrying out qualitative analysis of the answers provided. Moreover, additional interviewing with further authorities in the air pollution control sector could broaden the picture provided here of different divisions within the environmental lobby and their role in protecting the quality of the air by controlling industrial emissions. This approach was not adopted in the thesis because it was initially assumed that additional information from this source could not address questions that only residents who lived in certain areas of the city could answer. For this reason, the main focus of the survey was the household, not public servants or academic informants.

Ideally, data from structured and semi-structured interviews should be complemented by extensive census-like epidemiological studies. Even though government statistical data cannot provide all the necessary information to explain why child ill-health has been rising in densely polluted cities, it is always very useful to have aggregated data because they indicate general trends which may stimulate further research. A statistical record of non-reportable child and adult illness (e.g., respiratory disease), including identification of each reported case by its address, and perhaps also by household socio-economic circumstances, should be worked for in major cities where this information is not existent. It could be useful to link, for example, the geographical distribution of acute respiratory conditions to changes in the concentration of urban pollutants in relation to traffic flows, seasonal atmospheric fluctuations and levels of industrial emission.

Further, a related and important area of enquiry to emerge from these reflections is the reliability of methods that assess the impact of air pollution on health. Asthma would make a good case study as its cause is unknown (Department of Health, 1995a). Nonetheless, it is strongly suspected that asthma is connected to the presence in the atmosphere of man-made allergens; its incidence is increasing and, controversially, asthma has been associated with passive tobacco smoking (Chapter 7). The most common procedures for assessing the prevalence of asthma include self-reporting, personal monitors and the use of related indicators (e.g., visits to physicians, drug prescription, school absenteeism, hospital admission rates) However, there are numerous difficulties in measuring changes and defining causes of respiratory disease by these methods. The impact of air pollution on asthma sufferers is difficult to assess and there remains a degree of uncertainty as to whether increases in case numbers reflect a changed reality, or whether these are the result of different medical practices, improved technology or, simply, the reporters' increased awareness of the symptoms of the disease. It is, therefore, necessary to be cautious about the value of information derived directly from epidemiological reports, and critical of the methods these disciplines employ.

Lastly, it would be useful to extend this research into a more general discussion of the role of both the state and politics and committed scientists in regulating air pollution in cities and in safeguarding the well-being of different sectors of the population. The current state of air contamination in Houston has been established after thorough analysis of the following: monitored pollutants' measures published by city, state and federal agencies; severity of air pollution reported by residents of the surveyed households; and a comparison with other US and other countries' cities. Current high levels of ozone and sulphur dioxide found in the city indicated a failure of these institutions to promote residents' well-being. The research of the thesis has exposed limitations of federal and state industrial emission control and indicated the shortcomings of the national safety limits, the NAAQS. It has been concluded that a definite concentration of pollutants over time, particularly sulphur dioxide and ozone, in the most industrialized areas of the city, i.e., in the Ship Channel area, has reached levels above the permitted NAAQS there and elsewhere in the city. These themes provide material for further thought in three directions.

Ideally two additional measurements could be made which might extend the thesis' currently described origins of air pollution in Houston and so address the sources of exceeded limits through empirical research. First, the effect of implementation of the body of regulations on the actual concentrations of pollution in the city needs to be modelled. This could be done by estimating the changed volume of pollution over time since the 1970s in different locations within the city. In this way, inadequate laws to reduce the levels of pollutants could be singled out, be directly addressed and, consequently, modified. Second, notwithstanding that industry is by far the main source of contamination in Houston, a detailed account of the environmental regulation for transport and small industries would be useful in order to assess the impact of smaller sources of emission on the overall levels of air pollution in the city. Such a wide remit was not a realistic goal for this thesis given constraints of time.

Another line of thought would be to extend the thesis' analysis of the legislation to encompass the additional perspective of how rules imposed by the Texas environmental regulation body and the US federal government have prevented more rigorous and adequate environmental legislation. The number of measured hazardous days in Houston between 1980 and 1990 was high (Chapter 4). The incidence of reported child ill-health in 1990 in the surveyed households has been associated with polluted environments, but with levels of pollution lower than those specified hazardous according to the national safety standards. Present US health safety standards for the six regulated pollutants have been largely shaped by years of industrialists' lobbying which has succeeded in maintaining a favourable business atmosphere while disregarding the inevitable environmental consequences. Hence, there is a need for 'objective', i.e., non-partisan research and subsequent legislation on safety limits which may actually protect health and which are not the result of concession to powerful economic forces.

The last direction focuses, specifically, on the inherent uncertainty of scientifically established 'objective' pollutants thresholds and the long-running debates about defining risk. Without denying the imperative need to reduce industrial and other toxic emissions, defining the adequacy of accepted emission levels and the capacity of the environment to assimilate pollution without further damage, is a difficult point to resolve. Even if pollutants safety limits were more stringent than at present, they may still be inadequate to guarantee healthy environments everywhere. This is so precisely because many issues of risk are unresolved, and probably unresolvable, by science. There is, moreover, an enormous gulf between what scientists know or are likely to discover, and what needs to be known before decisions about environmental risks can be based on conclusive evidence (see, e.g., Adams, 1995; Beck, 1993; Yearley, 1991a; Douglas and

Wildavsky, 1983). Bio-medical advance in the last twenty years has found interactions between the mechanisms and effects of air contamination; however, these have not removed many uncertainties. On the contrary, uncertainties have proliferated with each new discovery. Pollutants standards thus may only be indicative of the *need* to protect the environment and the population rather than representing precise and uncontestable safe figures. Indeed, even if 'healthy' levels were politically and physically achieved, there is hardly any assurance that permitted emissions and acceptable levels of pollution would not cause *any* harm. For example, if other criteria were employed to assess the degree of risk for different populations and locations, if different technological tools were employed to monitor air pollutants, or if effects were measured in the long term, presently accepted standards may emerge as positively deficient. Whilst current US NAAQS are applied consistently in every US major city, it is necessary to determine whether the federal legislation matches the individual needs of each city. Atmospheric conditions such as high humidity and extreme heat in Houston may need individually tailored pollutant standards if the air is to remain reasonably healthy and pleasant.

The thrust of my research has been to initiate and prioritize an interdisciplinary approach in the analysis of the various dimensions that compose the theme of study. Within the environmental sciences there is an increasing interdisciplinary inclination as well as a parallel tendency to question the adequacy of the traditional sciences for explaining environmental problems. Interdisciplinarity is suggested as the natural normative response which is used in an attempt to expose and supersede disciplinary reductionism in environmental research (Leroy, 1995). The thesis has introduced a modest degree of interdisciplinary research as instrumentally and pragmatically sufficient, and has shared scientific information. Certainly, the thesis goes beyond the practical aspects of the issue and lays open venues for further investigation on the definition of interdisciplinary approaches necessitated by environmental and related matters. Interdisciplinarity should be at the heart of further work on the themes of environment and society. More importantly, the present research integrates the rising tide of literature that commits itself to a final break with a philosophical tradition which still insists that there is a rigidly defined science for people (social science) and others for nature (the biological and physical sciences).

8.4 Conclusion

When the relationship between economic growth, air pollution and child ill-health is duly contextualized, as this thesis has attempted to do, it is clear that neither air pollution nor child ill-health is natural or unavoidable. This was not a policy oriented thesis. However, the empirical research and the analysis of fundamental components of severe air pollution and economic growth in Houston suggest that once the hidden linkages that cause environmental degradation and ill-health have been understood, significant changes can be postulated not only for the legislative framework of air emission and pollution control but also in the area of economic policy. In order to promote both appropriate economic development and the formulation of efficient environmental policy it is clear that a more integrated and political research approach to the study of air pollution in major cities is needed.

Unless we change our approach to ecological and health problems, integrating the recognition that the underlying causes of these problems are political and economic, and acknowledge that there are crucial methodological and conceptual difficulties to the study of air pollution and ill-health in economically developed cities, we may not be able to reverse the effects of pollution on living tissues. R. Carson's book, *Silent Spring* (1962), whose words opened this research, informed the world of unacknowledged damage inflicted on nature by years of human economic activity. However, neither an overriding political strategy for the problem the book identifies (Dobson, 1995), nor a theory and method to approach overall environmental degradation existed in the 1960s. In the 1990s, however, these reasons cannot be used any more to justify deficient understanding of the contradictions of economic growth and further inaction to reduce air pollution. Indeed, an important justification for this thesis is its methodological and explanatory character, particularly for the political and economic aspect of environmental degradation and child ill-health in our cities.

APPENDIX A

HOUSEHOLD SURVEY AND SEMI-STRUCTURED INTERVIEWS

A.1 Selecting Study Areas within Houston

The sample areas within which the household survey was conducted in Houston were randomly selected and the selection was heavily influenced by three factors: the socio-economic features of the residential areas, their location in relation to industrial sources of air pollution, and their levels of measured air pollution. As discussed in Chapter 2, variation of these particular factors has been identified in the literature as crucial for promoting child ill-health.

The selection of areas was very important because each household needed to be clearly identified as part of a previously defined geographical and polluted area within the city, since child health had to be explored within the household as defined in Chapter 3. (This approach contrast with most epidemiological studies, which examine the health of children in schools or hospitals and limit their cases to a smaller number of children.) This identification was necessary because the field-work combined extensive and intensive research with the need for comparison of attributes of the household and the incidence of child ill-health. Therefore, the selection of two geographical areas responded to locational (when this was related to economic activity in the city), ecological and social characteristics: one near and the other far from the petrochemical complex and port facilities, one with highly polluted air and the other with considerably less polluted air; and both having poor and wealthy households.

The information initially used to identify characteristics of different geographical areas in Houston was elicited from the summary of population profiles of Houston public health annual reports published by the City of Houston Health and Human Services Department (1984-1988). This was, however, insufficient and inadequately qualified. The Department has divided the city into 11 geographical areas referred to as health service areas (HSAs), over which the city has administrative control of public health.[1] Demographic and socio-economic data in these publications were based on the 1980 census which was the most updated source of population data by the time of planning and conducting the survey (between January and June 1990). The corresponding figures for the 1990 census are included in this section for general information and comparison.

Certain criteria offered by the reports gave some indication of the characteristics of the households. Five criteria were most useful: location of the area within the city, average household income, percentage of households below the poverty line, percentage of single parents, and ethnic composition. As a result of the assessment, two HSAs were identified as most adequate to be explored, Magnolia in the east side of the city and South-West in the south-west of Houston:

Magnolia HSA is located in the east of the city close by the petrochemicals and port facilities in the Houston Ship Channel. According to the 1980 census, it presented diversity of socio-economic conditions among the population with 15.8% of families in the area living below the poverty line and 15.5% of households headed by single females (15.5%). The median household income in 1979 was $15,200. This figure hid the presence of very high-income households in this area as repeated visits to the area revealed. In the 1990 census, the corresponding figures were higher with 33.6% below the poverty level; 22.0% single female headed households; and the median income per household $17,658. In terms of ethnicity, Hispanics accounted for 71.8% of the population, Whites 20.9%, Blacks 5.4% with the reminder representing 1.9%.

Southwest HSA is located about 25 miles from industrial and port facilities in the South-West section of the city. A population of remarkably contrasting economic status lived in this area. In 1979, socio-economic indicators listed only

[1]The City of Houston Health and Human Services Department operates government-funded clinics in only 7 HSAs with 4 lacking any access to public clinics.

4.7% of families as falling below the poverty level; the median household income in 1979 was $22,515 per year; and 7.7% of the households were headed by single females. In 1985, the ethnic composition of the population was 76% White, 12.5% Black, 8.6% Hispanic and 2.9% other.

It should be stressed that a shift in the population occurred as a consequence of the economic recession in the 1980s (see section 4.3): residents from eastern sections of the city then moved to the South-West, where apartment rents had decreased significantly. Since the mid-1980s, therefore, an increasing, principally Hispanic low-income and *indocumentado* (illegal) population lived under the poverty line in the Southwest HSA (see Chapter 5, fn. 11). This change was reflected in the 1990 census with many more households living below poverty level (16.3%) and headed by female single parents (27.6%). According to the City of Houston Health and Human Services Department, however, the median household income per annum in the area, remained, high ($27,918), reflecting the undeniable presence of a number of comparatively wealthy inhabitants. However, as the thesis and the Urrutia-Rojas study (1988) have shown, this average masks the presence of extremely low-income households living in close proximity.

Although the population profiles generated by the Department provided a starting point from which to select the study areas within which the household survey was to be carried out, the geographical area contained within the boundaries of each HSAs was huge. This was a serious drawback because I needed to identify sub-areas of a manageable size, to make feasible conducting the research. The selection of smaller residential areas according to geographical location in Houston was done in relation to proximity to the industrial and petrochemical installations in the Houston Ship Channel. Levels of air pollution in different sectors of Houston were examined for the years 1989-1990 using the BAQC air pollution monthly reports, particularly for ozone and sulphur dioxide, in two distant stations, in the 9525 Clinton Drive site in the Ship Channel and at 13826 Croquet Drive in the

South-West (see Figure 3.2; see also Chapter 4). Information on the levels of air pollution in Houston was expanded significantly in later stages of the research by examination of the State of Texas TACB and the US EPA publications on air pollution.

A.2 House Sampling in the Selected Areas

Having identified the most suitable geographical areas near and far from sources of industrial air pollution for conducting the survey, and within the boundaries of Magnolia and the Southwest HSAs, 300 households had to be selected for interview for comparative study. This was done according to 'cluster sample' as defined by Vaus (1986) because the houses were situated within defined and clearly limited geographical areas.

I visited the surroundings of the oil and gas refineries as well as the South-West a number of times before choosing in which particular quadrants to carry out the household survey. The visits were very important because they enabled me to assess (both visually and through smell) the impact of the huge industrial and petrochemical developments in the surroundings of the Ship Channel, and to confirm both the presence of wealthy homes in the east side of Houston in the vicinity of the petrochemical plants as well as the presence of poor housing in the South-West far from polluting industry. The existence of low- as well as high-income households was verified by observing the external character and size of the dwellings, the state of outside gardens, whether the streets were paved, types of cars parked in driveways, and whether there were trees on the pavement and shops in the area.

The main criteria at this stage of the selection of households was to have a representative sample of similar low- and high-income households in the polluted and in the less polluted residential areas and that the households be located near each other. I mapped the area and identified the names of streets to be surveyed within the shortest possible radius because the size of the study areas had to be manageable. The selection of houses responded to the following procedure. In each, the polluted and the less polluted areas, 150 households had to be interviewed, with half being low- and half high-income households. Each house on a selected street had an equal chance to be interviewed. If the interviewee was not at the address on three separate attempts over a period of two weeks, or if there was no child in the household, then another household in the same street was added to the survey until the 300 household interviews were obtained. In this sense, the strategy for household selection was quasi-random sampling of houses because it was essential that there would be at least one child in a household and this was not known beforehand.

A.3 Semi-structured Interviews

Individual semi-structured interviews with various key informants were aimed at exploring their ideas on the state of health of the population and the environmental conditions in Houston. The purpose was to register the perspectives of professionals who were directly involved in the health care of the community and the control of air pollution in the city. The information given by the interviewees provided further contextual backdrop important for interpretation, but it was not the purpose of the research design to carry out qualitative analysis by interpreting the meaning of this information. I had a few questions designed for each interviewee but I used questions and responses to generate more questions and further information. One subject lead to another in such a way that I could cover the subject of investigation. The length of each interview varied considerably from 45 minutes with S.Klineberg to 2 hours with G. McMullen. I took notes in the interviews. The six unstructured interviews were carried out with:

Gene McMullen, Director, City of Houston Air Quality Control Bureau, February 1992

Dr. Aaron Mintz, Head of Paediatrics, Ben Taub County Hospital, February 1992

Dr. Steven Klineberg, Department of Sociology, Rice University, Houston; author of the first environmental survey in Houston, February 1992

Dr. Sulabaha Hardikar, City of Houston Health and Human Services Department, February 1992.

Dr. Virginia Moyer, Community Health, Paediatrics, L.B. Johnson County Hospital, February 1992; telephone interview

Ada Montalvo, Responsible for Casa María Volunteers Clinic, South-West Houston, July 1990

A.4 Statistical Analysis

Completed questionnaires were checked within a few days of the interview taking place and were then coded on to spread sheets in the field. These were later re-coded on to computer forms in England when the statistical analysis was started. Due to the large amount of information, the main frame computer facilities in the London School of Economics were used. The statistical package used was SPSS/VAX. Simple descriptive and inferential statistical analyses were carried out (Roberts, 1991; Healey; 1990; SPSS Inc, 1989; Norusis, 1988).

Univariate, bivariate and multivariate analyses were carried out and nominal and interval variables were used. Analysis of frequency was initially done to describe the composition of the household and the extent of child ill-health. The statistical function analyzed was cross-tabulations. Tables and graphs were used to display the frequencies and the relationships (Healey, 1990).

Some 'P-value' are shown in tables and figures only to denote the probability of the particular difference occurring by chance but with no purpose to conclude causality. (The P-value is shown only when it was less than 0.05, that is, when the relationship was statistically significant.).

A.5 Researcher's Position in the Survey

Being a female interviewer was an advantage for the purpose of gathering information on child health and household circumstances because these themes are usually associated with women's roles. Nonetheless, women were asked about issues that lay beyond the boundaries of the household, and which are usually left to men's management, such as air pollution, possible solutions to local environmental problems, and whether they were actively involved in local issues (see Burgess, 1991).

The White American and Hispanic population was not difficult to approach since the present researcher speaks both English and Spanish, the latter proving a great advantage. The overall response was very encouraging with respondents showing a remarkable degree of respect for the academic research as this kind of survey had never been previously undertaken in their area. Interviewees usually found the questions relevant to their concerns which encouraged them to expand further on the issues about which they felt most strongly. Personal interviewing in all cases was advantageous in minimizing the risk of introducing one category of response errors which might have resulted from different people's interpretation and management of the survey instrument.

In the semi-structured interviews, my credentials as a research student from the London School of Economics were particularly helpful. The interviewees not only showed great respect for the researcher but they also expressed their satisfaction at my interest in their particular city. Some interviewees were very eager to offer information notably the Director of Air Pollution Control in Houston and GPs in the public sector.

APPENDIX B

THE AIR POLLUTION AND CHILD HEALTH SURVEY (APCHS), HOUSTON, 1990

B.1 The English Questionnaire

The Air Pollution and Child Health Survey, Houston, 1990

Purpose
The purpose of this questionnaire is to collect information on industrial pollution in the city of Houston and on child health. Households within two areas in Houston have been selected for study. All information given by respondents is anonymous and it will be treated in complete confidentiality. The results of the survey will be part of the elaboration of a postgraduate dissertation.

Instructions
There are 30 questions and some of them include sub-questions. All the questions should be answered. Please, make a circle around the number of your selection. In questions where you are required to write words or numbers, do it in designated spaces (i.e. ____).

Start here.
1 Where do you live?

Sub-Division (eg. Westbury, Magnolia) ______________

Zip code ______________

Live in: Apartment House Mobile Home Condominium Other ______

2 How many people live in your house ______________

3 How many out of them are children? ______________

4 Where do you take your children for medical care?

1. Public clinics and hospitals 2 Private clinics and hospitals
3 Both

5 When was the last time your child/children visited physicians, clinics or hospitals in Houston?

1. 4 Weeks ago 2 6 Months ago 3 1 Year ago
20. 3 Years ago or more 5 Have never visited

6 Why don't they visit medical facilities more often?

1 Child/children is healthy 2 Physicians are too expensive
3 Clinic is far away 4 Child gets better alone
5 Use foreign medicines 6 Look for medical help

7 Does your child/children suffer from any of the health problems listed below?

1 Frequent chesty coughs	2 Allergy
3 Cough with colds	4 Chest sounds wheezy/whistling
5 Ear infections	6 Bronchitis
7 Sinusitis	8 Asthma
9 None of them	10 Other ___________

8 How long has your child/children lived in the present house?

1 Less than 1 year   2 Between 1-3 years   3 3 - 5 years
4 More than 5 years

9 How long does your child/children spend outdoors, e.g. playing with friends, going to next-door store, during recess at school?

	Hours
In one typical Summer day	_________
In one typical Winter day	_________

10 What do you think of the quality of the outdoor air in your neighborhood? (Consider smells and clearness of the air). Is it..?

1 Clean	2 Sometimes smells of chemicals
3 Very often smells of chemicals	4 Smells of garbage
5 Other _____	

11 Have you noticed any of the following changes or deterioration in your child/children's health at times when industrial pollution (eg. smog, smell) is particularly high?

1. Cough	2 Stomach problems	3 Headaches
4. Breathing problems	5 Allergy	6 Other
7. There are no changes	8 Do not know	

12 Were environmental conditions in previous child/children's home (if any):

1. Better   2 Worse   3 Similar   4 Do not know
5. Other ________

13 Why do you and your family live in your neighborhood?

1 Grew up here	2 Rents are low
3 Have family and friends	4 Close to work
5 Area has good reputation	
6 Other ________________________________	

14 A. What sort of employment do you (the mother) have,

1 Employee	2 Employer	3 Unpaid
4 Self-employed	5 Temporary	

and B. What kind of work do you do?

6 Services (public, domestic) 7 Industrial 8 Housework
9 Business 10 Professional 11 Other

15 Does anyone in your house spend time working in polluted and unhealthy places (eg. in smelters, in chemical industries, with pesticides, etc.)?

1 Yes 2 No 3 Do not know

15.1 If Yes, in what occupation and where? __________ ____________

16 Before you (biological mother) gave birth, have you ever been exposed to harmful and toxic environments, such as in work places and/or in previous living areas?

1. Yes 2 No 3 Do not know

17 Does father of child/children live in the house?

1. Yes 2 No

18 Does father/stepfather support the family financially?

1. Yes - father 2 No 3 Yes - stepfather

19 Do you find any difficulty in buying any of the following items?

1 Education (eg. books, fees, supply) 2 Health (eg.medicines, visits)
3 Leisure (eg. holidays, outings) 4 Clothing and shoes
5 Rent or Mortgage 6 Food
7 Nothing 8 Other ________________

20 Fill in: Approximate weekly (W) or monthly (M) expenditures in the family.

		$
1	Food (W)	__________
2	Health care (M)- visits, insurance, etc.	__________
3	Education (M)	__________
4	Rent or mortgage (M)	__________
5	Utilities (M)-electricity, etc.-	__________
6	Various -clothes, transportation, etc.-	__________

21 Mark one: total monthly income in your home (include additional benefits).

1 Less than $700
2 $700-1,000 3 $1,000-1,500 4 $1,500 -2,000
5 $2,000-2,500 6 $2,500-3,000
7 More than $3,000

22 How many bedrooms are there in your house? ______

23 Which of the following do you have in your house?

1 Running water 2 Electricity 3 Sewer
4 Central Gas 5 Telephone

24 Do you use any of the following air conditioners in your house?

1 Fans 2 Single air conditioner 3 None
4 Central air conditioning 5 Gas heating 6
Heaters

25 Have you noticed any rising dampness inside your house (eg. on the walls, ceiling)?

1 Yes 2 No 3 Do not know

26 Do other parents complain that children in your neighborhood and/or children in the school, often suffer from any of the following health problems?

1 Cough 2 Stomach problems 3 Headaches
4 Breathing problems 5 Allergy 6 Other
7 Do not complain 8 Do not know

27 Taking into consideration both, the number of accidents in the chemical industry in Houston (the most recent happened in 'ARCO' plant in the 'Ship Channel' area, on 7/5/90) and toxic emissions from the chemical industry (found in water and air), do you feel that the government should be more concerned about citizens' health safety and the quality of the air within your division and in the city of Houston?

1 Yes 2 No 3 Do not know

28 In what way do you feel the authorities should help safeguard your child/children's health?

1 Assist people in rehousing programs away from noxious industries
2 Close down local chemical industries
3 Provide more/better medical facilities in your vicinity
4 Other ____________________

29 Point out the problems you feel much concerned about the area/neighborhood where you live.

1 Security (eg.police, patrols)
2 Health facilities (eg. clinics, hospitals)
3 Industrial pollution (eg. smells, noises)
4 Housing and schools
5 Basic Services (eg. trash collection, transport, lighting)
6 Water quality
7 Other ____________________

30 Have you and/or other people in your neighborhood expressed (by means of letters, petitions, demonstrations, political campaigns, etc.) your concern and discontent over environmental conditions in your area?
1 Yes 2 No
If Yes, when? how? Specify. ____________________

B.2 The Spanish Questionnaire

ENCUESTA: Contaminación Ambiental y la Salud de los Niños, Houston, 1990
(The Air Pollution and Child Health Survey, Houston, 1990)

Propósito
El propósito de esta encuesta es juntar información referente a la contaminación industrial en la ciudad de Houston y a la salud de los niños. Hogares en dos zonas de la ciudad han sido seleccionadas para este fin. Toda información recibida es anónima y será tratada confidencialmente. Esta será utilizada en la elaboración de una tesis doctoral.

Instrucciones
Esta encuesta consta de 30 preguntas y entre ellas algunas tienen preguntas derivadas. Marque el número/s de la respuesta/s elegida. Donde se requiera que escriba palabras o números, hágalo en los espacios designados (ej. __). Todas las preguntas deben ser respondidas. La encuesta está dividida en 4 secciones. El término 'niños/sa' significa indistintamente: niño, niña, niños y niñas. El término general 'casa' implica toda clase de vivienda: apartamento, hogar móbil, condominio, casa, etc.

Comience aquí:
1 Dónde vive?

Sub-división (ej. Magnolia, Westbury) ________________
Código postal ('zip code') ________________

Vivo en: Apartamento Casa Casa 'Mobile' Condominio
Otro _______

2 Cúantas personas habitan en su casa? ______

3 Cúantos de ellos son niños? ______

4 Dónde lleva a sus niños/a cuando necesitan ayuda médica?

1 Clínicas y hospitales públicos 2 Clínicas y hospitales privados
3 Ambos

5 Cuándo fue la última vez que sus niños/a visitaron un médico, clínica o un hospital? Hace:

1 Cuatro semanas 2 Seis meses 3 1 año
4 3 años o más 5 Nunca visitan 6 No sé

6 Por qué sus niños/a no visitan más frequentemente las facilidades médicas?

1 Los niños/a son sanos 2 Las visitas médicas son muy caras
3 La clínica está lejos 4 Se mejoran sin ayuda médica alguna
5 Uso medicinas propias 6 Los llevo cuando es necesario

7 Tienen sus niños/a alguno/s de los siguientes problema/s de salud?

1 Frecuente tos pectoral
2 Alergia
3 Tos con resfríos
4 Silbidos en el pecho
5 Infección de oídos
6 Bronquitis
7 Sinusitis
8 Asma
9 Ninguno de éstos
10 Otro ___________

8 Cuánto tiempo han vivido sus niños/a en la casa actual?

1 Menos de 1 año
2 Entre 1 y 3 años
3 Entre 3 y 5 años
4 Más de 5 años

9 Cuánto tiempo pasan sus niños/a fuera de la casa, por ejemplo, jugando con amigos, yendo a los negocios cercanos, durante los recreos en las escuelas, encada uno de los siguientes casos?

	Horas
En un típico día de verano	_______
En un típico día de invierno	_______

10 Cómo encuentra la calidad del aire en su barrio? (considere los olores y la visibilidad)

1 Limpio
2 A veces hay olores químicos
3 Casi siempre hay olores químicos
4 Hay olor a basura
5 Otro ______

11 Ha notado usted algunos de los siguientes cambios o deterioro en la salud de sus niños/a cuando la polución industrial (ej. humo, olor químico) es particularmente alta?

1 Tos
2 Problemas de estómago
3 Dolores de cabeza
4 Dificultades en respirar
5 Alergias
6 Otros _________
7 No hay cambios
8 No sé

12 Era el medio ambiente (aire, agua, limpieza) en casas donde sus niños/a habitaron previamente:
1 Mejor 2 Peor 3 Similar 4 No sé 5 Otro ____

13 Por qué elijió vivir en este barrio?

1 Nací y crecí en el lugar
2 Las rentas son bajas
3 Tengo amigos y familiares
4 Está cerca del trabajo
5 Tiene buena reputación
6 Otro ___________

14 Qué empleo tiene,
1 Asalariada (empleada)
2 Contratante
3 No recibe pago
4 Independiente
5 Temporaria

y , qué clase de trabajo hace ?
6 Servicios (públicos, domésticos) 7 Industrial 8 Ama de casa
9 Académico 10 Comercio 11 Otro ______

15 Alguien en su casa que trabaja bajo condiciones no saludables, sucias y/o tóxicas (por ej. en fundiciones, en industrias químicas, con pesticidas, etc.)?

1 Sí 2 No 3 No sé

15.1 Si hay alguien, cuál es la ocupación y dónde trabaja?

_______________ _______________

16 Estuvo usted (madre biolólogica de niños/a) expuesta a materiales peligrosos/tóxicos, antes/ durante sus embarazos, tanto en lugares de trabajo y/o en áreas de residencia ?

1 Sí 2 No 3 No sé

17 Habita el padre de los niños/a en la misma casa?

1 Sí 2 No

18 Ayuda el padre/padrastro de sus niños/a en los gastos diarios de su familia?

1 Sí-padre 2 No 3 Sí - padrastro

19 Hay en la siguiente lista algo que le es particularmente difícil pagar?

1 Educación (ej. libros, costos, materiales) 2 Cuidado médico
3 Diversiones (ej. vacaciones, salidas) 4 Ropa y zapatos
5 Renta/Hipoteca 6 Alimentos
7 Nada 8 Otro _________

20 Complete: gastos semanales (S) omensuales(M) que hay en su familia.

	$
1 Alimentos (S)	_________
2 Gastos médicos (M)(visitas, medicinas, etc.)	_________
3 Educación (M)	_________
4 Renta/Hipoteca (M)	_________
5 Utilidades (gas, electricidad, agua, teléfono; M)	_________
6 Gastos Varios (ropa, transporte, etc.; M)	_________

21 Señale: ingreso aproximado por mes en su casa (incluya todo beneficio adicional)

1 Menos de $700
2 $700 - 1,000 3 $1,000 - 1,500 4 $1,500-2,000
5 $2,000 - 2,500 6 $2,500 - 3,000
7 más de $3,000

22 Cuántos dormitorios hay en su casa? _________

23 Hay en su casa ...

1 Agua corriente 2 Electricidad 3 Cloacas y desagüe
4 Gas central 5 Teléfono

24 Usa en su casa algunos de los siguientes acondicionadores de aire?

1 Ventiladores 2 Aparato acondicionador 3 Ninguno
4 Aire acondicionado central 5 Calefacción a gas
6 Calentadores

25 Hay humedad en su casa (ej. en paredes, techo)?

1 Sí 2 No 3 No sé

26 Ha notado o escuchado por medio de otros padres/personas, que niños en su vecindario o en la escuela se quejan de algunos de los siguientes problemas de salud?

1 Tos 2 Estomacales 3 Dolores de cabeza
4 Dificultades en respirar 5 Alergias 6 Otros ________
7 No se quejan 8 No sé

27 Teniendo en cuenta los accidentes sucedidos en la industria química en Houston (el más reciente de ellos en 'Arco' en el Ship Channel, el 7/5/90) y los peligrosos materiales tóxicos que liberan (en el agua y el aire) las plantas químicas, cree usted que el gobierno debería preocuparse más de la salud de los habitantes y la calidad del aire en su vecindario y en toda la ciudad de Houston?

1 Sí 2 No
3 No sé 4 Otro ____________

28 De qué manera cree que las autoridades deberían ayudar a cuidar la salud de sus niños/a?

1 Asistiendo a familias a mudarse a zonas alejadas de las industrias químicas
2 Cerrando la mayoría de las plantas en su vecindario
3 Proveyendo más/mejores clínicas públicas en su vecindario
4 Otra ________________________

29 Señale qué problemas de su vecindario le preocupan.

1 Seguridad (ej. policía, patrullas)
2 Salud (ej. clínicas, hospitales)
3 La contaminación industrial (ej. el aire, los olores, los ruidos)
4 Viviendas y escuelas
5 Servicios básicos (ej. transporte, alumbrado, colección de basura)
6 La calidad del agua
7 Otro ________________________

30 Ha usted y/o vecinos expresado (por medio de cartas, peticiones, campañas políticas, etc.) su preocupación y descontento por las condiciones ambientales en el área de su residencia?

1 Sí 2 No

30.1 Si 1, cuándo, cómo? Especifique. ________________________

APPENDIX C

SOURCES OF INFORMATION

C.1 The Regional Surveys

The findings of two large surveys were consulted in this thesis, the Houston Area Survey and the Texas Environmental Survey (Klineberg, 1990, 1991). Both surveys were carried out by personnel in the Houston Rice University under the direction of S. Klineberg, Department of Sociology. They were employed in the current study for their information regarding the views of Houston and Texas residents on the natural environment and the prospects for improving the quality of life in the city.

The Houston Area Survey (1991; n=betwen 412 and 679 households) included environmental issues among other city concerns and has been carried out annually since 1982. It aimed to explore the ways Houston residents responded to a 'variety of trends that are transforming American society and challenging traditional assumptions' (Klineberg, 1991). The Texas Environmental Survey (1990; n=1000 Texans; Klineberg, 1990a) addressed environmental pollution in the State of Texas and interviewed residents across the state. The 1990 TES was the first major state-wide survey of environmental concerns.

In contrast with the APCHS, the Houston and the Texas surveys are only descriptive since the background of the respondents was not known. Their sample population was selected through a randomly generated list of telephone numbers, every resident having an equal chance of being interviewed, and interviews were conducted by telephone. The participating population in the APCHS was causally linked by geographical and socio-economic characteristics of their households. The HAS and the TES nonetheless offer important information on the state of Houston's wider environmental reality, reinforcing the findings of the thesis. They also strengthen the value of the residents' views for the purpose of political decision-making on economic growth and environmental protection.

C.2 Economic and Historical Sources

Information on the characteristics of contemporany Houston was derived from publications by two central economic bodies: the Port of Houston and the Greater Houston Partnership (previously known as Houston Chamber of Commerce). These sources were used for eliciting information on Houston's economic activities, on economic standing within the nation as well as demographic changes, and on the city's dimensions and weather. Literature on the economic development of the city and the rise of environmental degradation over time in the Houston region was obtained from secondary sources which had employed primary documentation, e.g., Pratt, 1980, Williamson, 1963.

Important information was also extracted from two major local newspapers, the *Houston Chronicle* and the *Houston Post*. These provided continual update on issues related to environmental pollution, industrial accidents and the state of the public health service in Houston. In addition, UK newspapers were used for further comparative reference, particularly on problems associated with air pollution and health in the UK.

C.3 Scientific Publications

The scientific literature employed focused on the biological, ecological and medical aspects of air pollution and ill-health in major cities. Numerous scientific journals and additional literature including government reports, non-governmental studies and newspapers were consulted. In particular, scientific publications were examined to address the ecological effects of toxic emissions in major cities, to understand the biomedical impact of air pollution on human health, and to identify the epidemiological features of child ill-health and air contamination during the period between the 1950s and 1990s. Because the study of the physical relations between environmental pollution and human health has been growing at a fast pace continual updating by the researcher was essential to keep up with new findings. This process was accompanied by the evaluation of established investigations and the outcomes of new ones.

C.4 Air Pollution Measures

The sources of air pollution statistics were the three governmental agencies operating in the city of Houston, the Air Quality Control Bureau (AQCB), the Texas Air Control Board (TACB), and the US Environmental Protection Agency (US EPA). As established in Chapter 4, the state of air pollution in the city Houston was assessed by examining three indicators over time: first, the attainment levels of the US government safety standards of the six regulated air pollutants, PM-10, ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and lead; second, the Pollution Standard Index which measures how hazardous the air is overall by presenting only one number in the scale from 0 to 100 indicating the degree of health risk; and third, comparisons between concentration trends of air pollution in Houston and in other US cities. The source of data to establish the degree of air pollution in Houston according to these indicators originated in three governmental institutions of air pollution control:

The City of Houston AQCB operates a network of 16 air sampling sites distributed throughout the City. Six continuous monitoring stations work seven days a week providing hourly averages of gaseous pollutant concentrations and meteorological parameters. Continued monitored data reach the Bureau's office on phone lines. At ten sites, air sampling devices filter particulate matter from the air. The inhalable particulate (PM-10) samplers operate every 6th day or in some cases every other day and also yield 24-hour average measurements. In addition to sampling the six pollutants for which the US EPA has established NAAQS (see section 4.4), the particulate filters are analyzed for nitrates and sulfates and other potential air contaminants (e.g., VOCs).

The air quality reports by the TACB (presently renamed Texas Natural Resource Conservation Commission) are based on routine measurements from all of the continuous and non-continuous monitors operated by the agency and local government agencies, i.e. the City of Dallas, City of Fort Worth, City of Houston, El Paso City-County Health District, and Galveston County Health District. They provide the data for regional and also local levels of air pollution. In addition, the National/Texas Comparison statistics and discussion for MSAs were extracted from TACBs publications.

Two types of US EPA documents were consulted, first, those dealing with air pollution trends over time in cities, and second, special publications on three themes, environmental lead, passive tobacco smoking, and cancer risks from outdoor air pollution (US EPA 1986, 1992 and 1990b respectively). The levels of regional and city air pollution were obtained from reports and various EPA publications. US EPA documents provided the data for analyzing changes in air pollution trends over time and the historical data for Houston local air pollution measurements since the start of national standardized control at the beginning of 1970, as well as the levels of air pollution in other US cities and MSAs for the period between 1981 and 1990. The US EPA air pollution reports are the result of measuring both actual concentrations of air pollutants measured at selected sites throughout the country, and emissions (based upon the best available engineering estimations).

C.5 Public Health Documents

The official health statistics published by the City of Houston Health and Human Services Department were the principal source of information used to assess the state of public health in the city. Those consulted covered the years 1984 to 1991.[1] Government local health data is presented in two formats: the city-wide measures, and the measures of the health service areas (HSAs, see Appendix A.1).

Health statistics used in the current study are based on age-adjusted death rates, as opposed to crude rates. Age-adjusted rates are calculated considering the differences in the age structure of the sub-populations of cities. This is important for comparisons because, if there are major differences in the age structure of the various population categories and if the risk of death varies with age, crude rates comparisons could lead to incorrect conclusions (mortality rates are directly adjusted to 1940 US census population age distribution, City of Houston Health and Human Services Department, 1984-1988, p. xxxvi). The 1989 and the 1990 rates which use population data in the denominator for the rate calculation have not been directly compared. This is because 1989 rates use the population estimates based on the 1980 census data as the denominator, while the 1990 rates used the 1990 census data as the denominator. Nonetheless, the 1989 and 1990 health rates which do not use population data in the denominator can be compared. Examples are both infant and maternal mortality rates (City of Houston Health and Human Services Department, 1989-1990, p. xxxiv).

Morbidity statistics include only reportable diseases. There are 52 reportable diseases and these are grouped under 4 clusters: selected infectious diseases (hepatitis, H. influenza infections, aseptic meningitis, salmonellosis, shigellosis, and campylobacteriousis); sexually transmitted diseases (syphilis, gonorrhea); tuberculosis, AIDS, and measles; and some occupational diseases. Reporting of disease is required by law and is either mailed or telephoned to the health authority by physicians, hospitals, nurses, veterinarians, laboratories, clinics, day care centres, or restaurants. The completeness of reporting of non-fatal, but reportable illness is, in reality, difficult to assess. Of the 52 reportable diseases, those which require

[1] Laura Shelton, the Project Coordinator in the Health and Human Services Department has kindly provided me with the updated version of the annual health reports, The Health of Houston I and II .

extensive long-term treatment and tracing of cases, or have a high mortality, or alternatively have a readily identifiable intervention to prevent exposure of contacts are most likely to be reported. In this way, the incidence of some diseases might appear higher than reported in the public health statistics (City of Houston Health and Human Services Department, 1984-1988).

The only available, and rather inadequate documentation on the geographical variations of mortality within the city was in the form of HSAs. However, the health information that these documents provide was insufficient to answer the queries of this thesis. The geographical boundaries of each HSAs are very extended and include large and varied populations, hence only demographic indicators - i.e., age, sex and ethnicity - have been correlated with health parameters.

Official medical sources were used to obtain information on *cancer* mortality and cancer risk, particularly those of respiratory origin, in Houston and in the USA. The main documentary sources were :

i. Texas Cancer Council, the Texas Department of Health and the University of Texas M.D. Anderson Cancer Center (1991), *Impact of Cancer on Texas*, Houston: The University of Texas M.D. Anderson Cancer Center.

ii. US Environmental Protection Agency (1990), *Cancer Risk From Outdoor Exposure To Air Toxics*, Vol II.

iii. City of Houston Health and Human Services Department, City-wide Measures, Houston. Reports for the years 1984 to 1991.

C.6 Libraries

A number of very resourceful libraries were consulted in Houston. A most useful institution was the M.D. Anderson Cancer Center Library at the University of Texas. No less important were the libraries in the School of Public Health, also at the

University of Texas; and the well equipped library of Rice University, the University of Houston Library, and the main Public Library in Houston.

In the UK, the main libraries used were the British Library of Political and Economic Sciences, the Science Reference and Information Service of the British Library, local libraries, and the inter-library service.

APPENDIX D

THE RECOGNIZED HEALTH EFFECTS OF AIR POLLUTANTS IN CITIES

The health effects of isolated air pollutants have been studied for some time now and many of their adverse consequences widely acknowledged. A common feature of air pollutants is their high toxicity which is harmful to humans and animals, has adverse effects on the natural and built environment, spoils clear visibility in cities and plainly contaminates the air. The most common individual air pollutants found in cities and presently regulated in the USA and other countries are ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO_2), nitrogen dioxide (NO_2), particle matter (PM-10), and lead (Pb). In addition, volatile organic compounds (VOCs) are recognized contaminants, but these are not officially regulated.

Ozone is a major component of photochemical air pollution in cities (and in rural areas). Ground level ozone is formed by the interaction of nitrogen oxides and light with VOCs acting as catalysts, most often in hot weather. Ambient levels of ozone not only affect people with impaired respiratory systems, such as asthmatics, but healthy adults and children as well. Whereas short-term and high-dose exposure to ozone has been found to alter pulmonary functions, little is known about the respiratory health effects of long-term exposure to high-to-moderate concentrations of ozone. Ozone exposure is associated with an increased risk of cough and respiratory illness. Moreover, it has been shown that children in zones with higher annual ozone concentration are more likely to have abnormal lung function, with respiratory flow rates less than 70% of predicted value (Schmitzberger *et al.*, 1992). Though less well established in humans, animal studies have demonstrated that repeated exposure to ozone for months to years can produce permanent structural damage in the lungs and accelerate the rate of lung function loss and ageing of the lungs.

PM-10 s are possibly the most worrying of the cocktail of pollutants pumped out by road traffic (Friends of the Earth, 1995). PM-10 is associated with increased asthma attacks and mortality. Airborne particulates at concentrations previously considered safe are considered a potential risk factor for asthmatics (Schwartz *et al.*, 1993).

Sulphur dioxide is produced when coal in burned. Since the 1950's clean air Acts, sulphur dioxide levels have decreased. Power stations are by far the biggest contributors, although industrial and domestic use also creates sulphur dioxide. This pollutant is particularly known to cause wheezing and in the long term to affect patients with asthma (National Asthma Campaign, 1994; Bach, 1972).

Common major concerns for human health relating to inhaled *PM-10* and *sulphur dioxide* include the effects on breathing, aggravation of existing respiratory and cardiovascular disease, alterations in the body's immune system, damage to lung tissue and premature mortality. The major subgroups of the population that appear likely to be most sensitive to these pollutants include individuals with chronic obstructive pulmonary or cardiovascular disease, individuals with influenza, asthmatics, the elderly and children.

Nitrogen dioxide is present in vehicle emissions (exhausts) from both diesel and non-diesel engines. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection, such as influenza (US EPA, 1991, pp. 1-5, 1-15). It is an important precursors to ozone, to PM-10 concentrations and to acidic precipitation. Exposure to nitrogen dioxide can increase the sensitivity of asthma sufferers to allergic triggers such as pollen and house dust mites; short-term rises in nitrogen dioxide concentrations are associated with increased hospital admissions for asthma and respiratory disease; and longer-term nitrogen dioxide exposure is associated with reduced lung function and croup in children (Friends of the Earth, 1995).

The health threat from *carbon monoxide* is most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Healthy individuals are also affected but only at higher concentrations of the pollutant. Carbon monoxide enters the blood-stream and reduces the speed of the delivery of oxygen to the body's organs and tissues. Exposure to elevated carbon monoxide levels is associated with impairment of visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks. The effects of short-term exposure are still unclear but continued or frequent exposure to concentrations higher than those normally found in the ambient air may cause increased incidence of acute respiratory disease in children. Carbon monoxide is produced by the incomplete combustion of carbon-containing materials like wood, coal and oil. The main sources which affect human health are smoking, car exhausts and unflued heating or cooking appliances (National Society for Clean Air and Environmental Protection, 1995).

Lead affects numerous aspects of human health and exposure to lead can occur through multiple pathways, including inhalation of air, dye and ingestion of lead in food, water, soil or dust. Lead accumulates in the blood, bone and soft tissue. Because it is not readily excreted, lead also affects the kidneys, liver, nervous system and blood-forming organs. Excessive exposure to lead may cause neurological impairment, seizures, mental retardation and behavioural disorders (e.g. Baghurst *et al.* 1992; Needleman *et al.*, 1979; Caprio *et al.*, 1975). Even at low doses, exposure to lead is associated with changes in fundamental enzymatic energy transfer and homeostatic mechanisms in the body. Foetuses, infants and children are especially susceptible to low doses of lead, often suffering central nervous system damage and reduction of IQ.

Volatile organic compounds are precursors to ozone formation and toxic properties of some VOCs such as *benzene* . This is of great concern because benzene is a human and animal carcinogen. It is emitted into the air from the processing and use of petroleum products and is a by-product of fuel combustion. It is present in both leaded and unleaded petrol (Friends of the Earth, 1995). People exposed to high levels of benzene have a small but definite increase in the risk of developing non lymphocytic leukaemias. Petrol station attendants have a significantly elevated risk of contracting leukaemia. Monitoring of VOCs in Houston is therefore very important because of extensive petrochemical industry activity and car emissions.

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